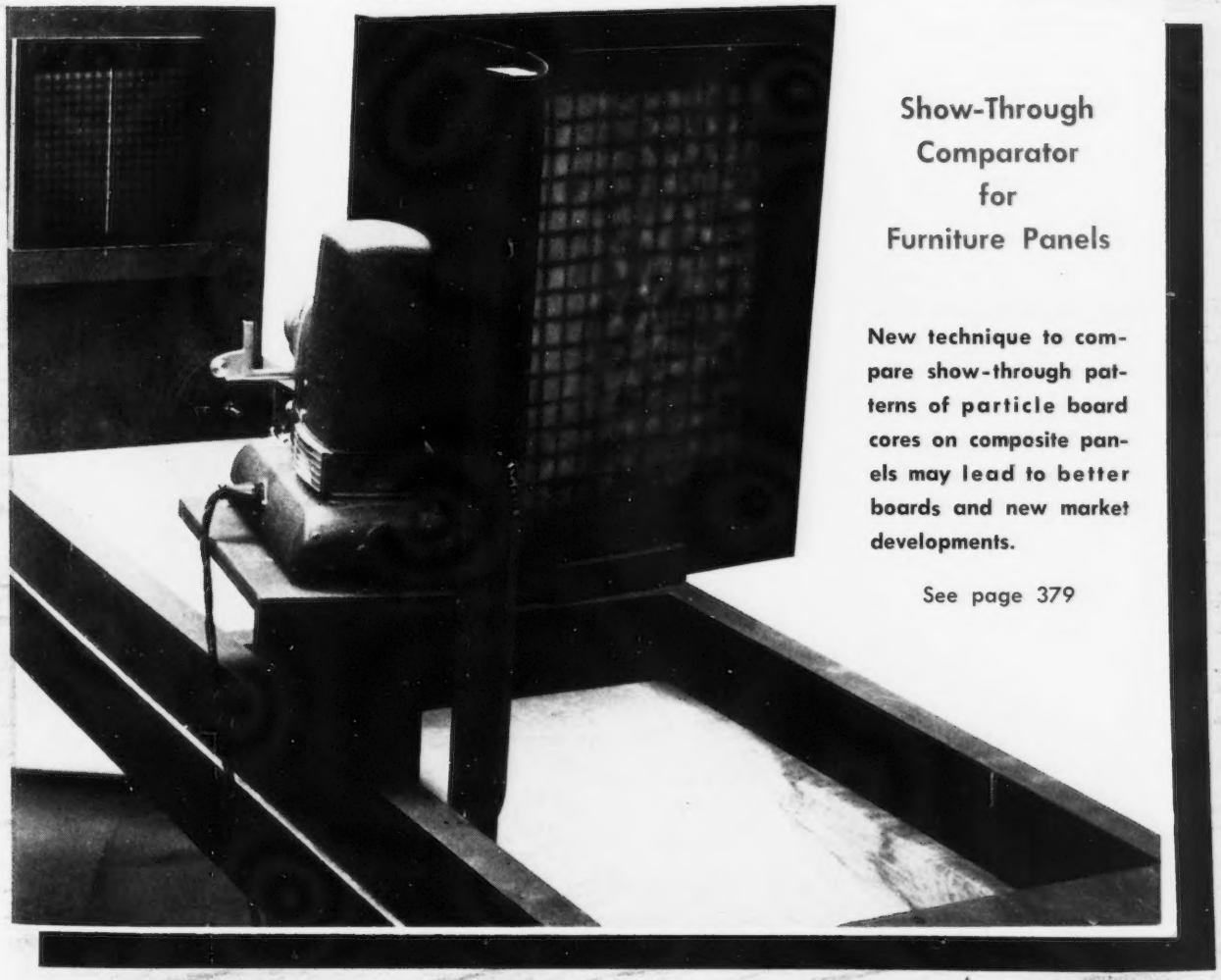
FOREST PRODUCTS JOURNAL

FOREST PRODUCTS RESEARCH SOCIETY



Show-Through Comparator for Furniture Panels

New technique to compare show-through patterns of particle board cores on composite panels may lead to better boards and new market developments.

See page 379

Vol. X, No. 8

1960/AUGUST

MISSING: ONE GLUE LINE

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FOREST PRODUCTS JOURNAL

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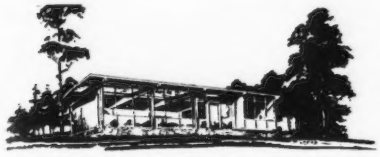

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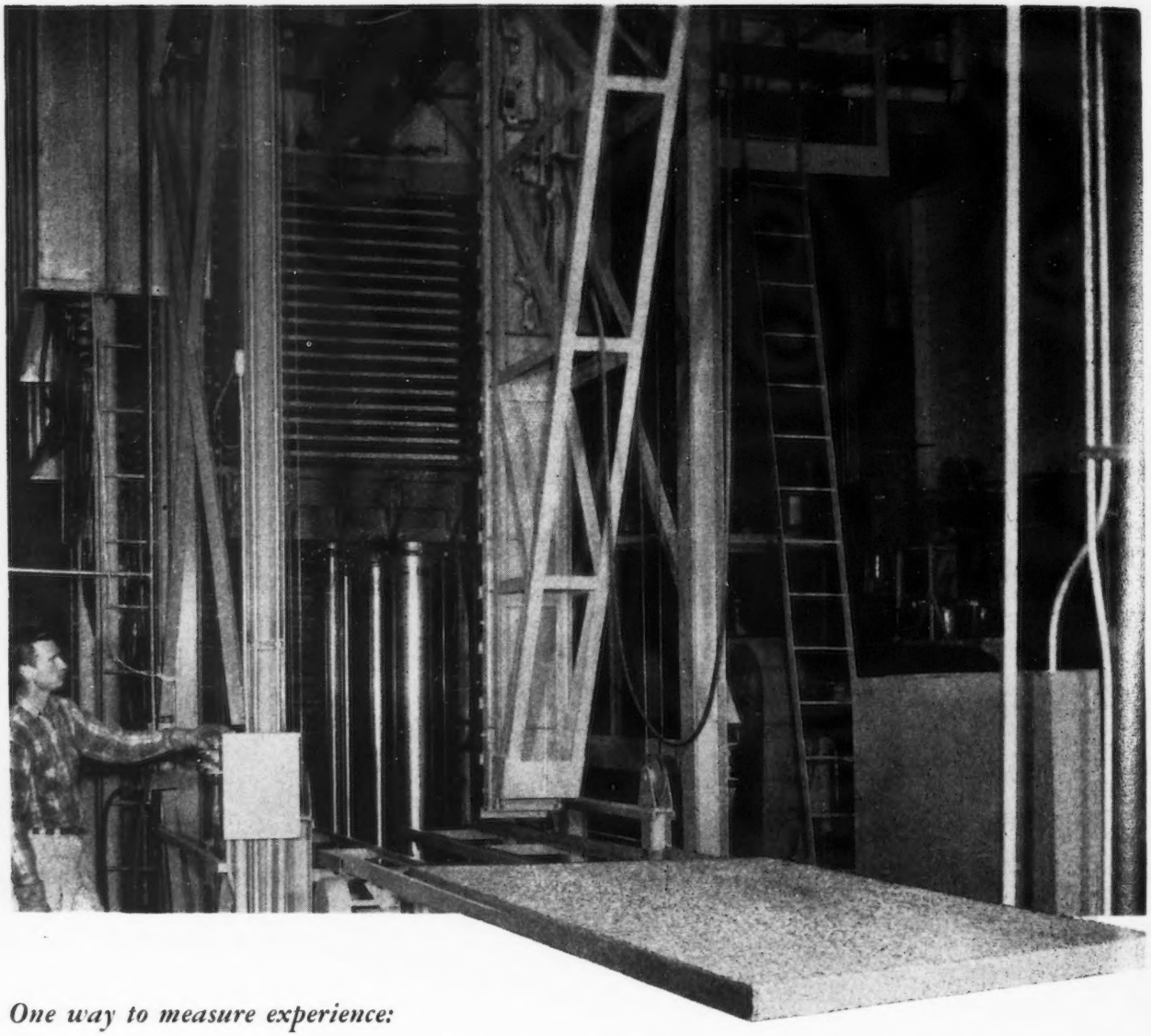

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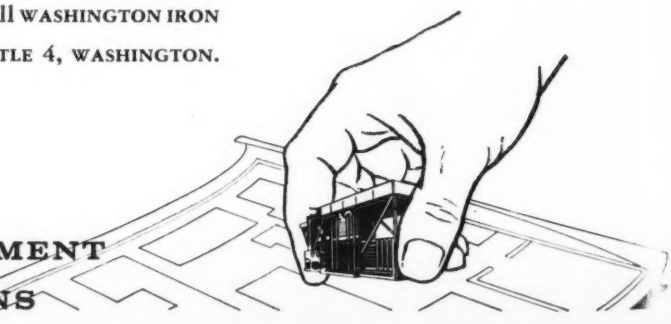

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Initial sanding of contour on the intermediate support for the pew is done on a drum sander with CLOSEKOTE GARNET Paper DURABONDED, 60-E.

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f Christ, Newton, N. C. The pews
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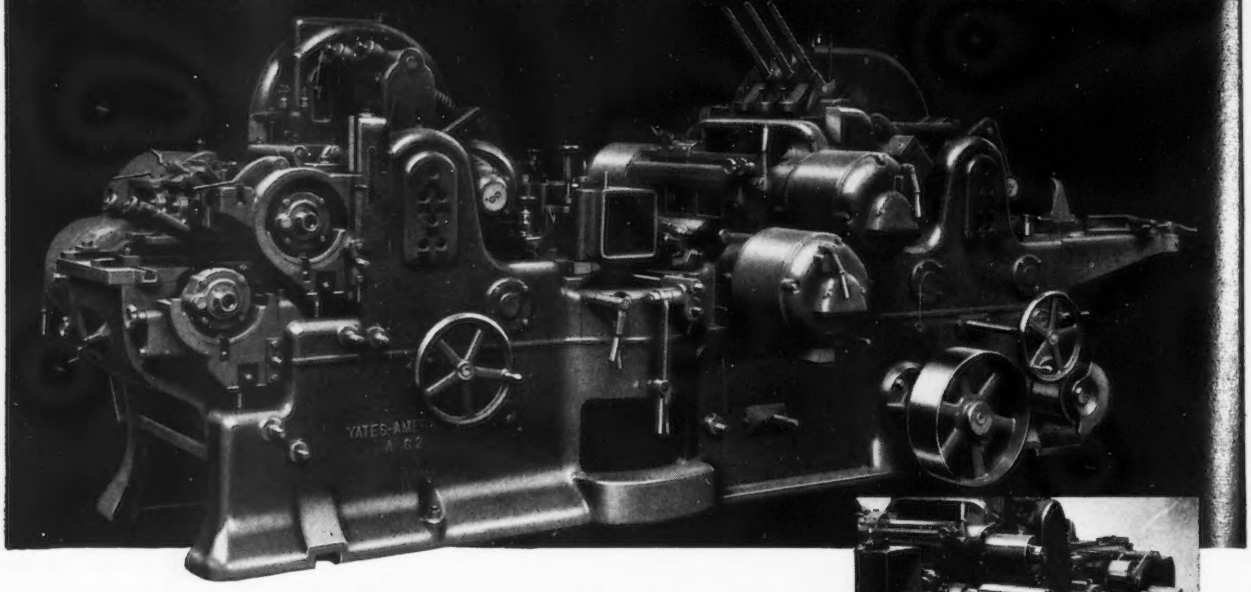

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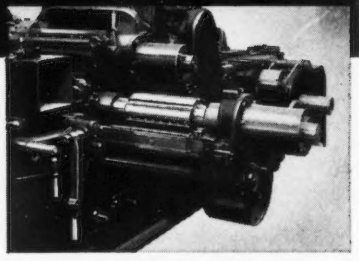
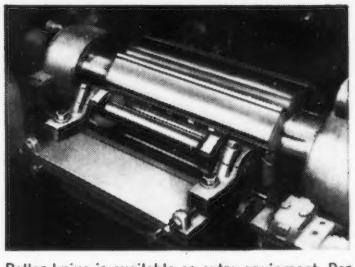
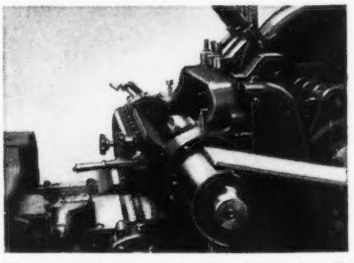


The bottom head can be readily withdrawn to make it accessible for grinding or changing knives. Note the built-in jointer.



Roller knive is available as extra equipment. Permits fast, accurate setting of knives. Easy to use and adjust.



The top head yoke carries the chipbreaker, the head, and the bar-after-cut. The bar can be raised and returned to its original position, quickly releasing jams without disturbing the set.

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Important FPRS Dates

August 29–September 10: Fifth World Forestry Congress, Seattle, Wash.
September 28–October 1: Midsouth Section Meeting, Memphis, Tenn.
October 13–14: Ohio Valley Section Meeting, Evansville, Ind.
October 14–15: Northeast Section Meeting, New Haven, Conn.
October 16–17: Executive Board Meeting, Madison, Wis.
October 16–22: National Forest Products Week, Nation-Wide.
October 17–18: Pacific Northwest Section Meeting, Tacoma, Wash.
October 19: Great Lakes Section Meeting, Grand Rapids, Mich.
October 20–21: Upper Mississippi Valley, Section Meeting, St. Paul, Minn.
October 21: Northern California Section Meeting, Stockton, Calif.
October 27–28: Midwest Section Meeting, Madison, Wis.

FPRS News-Digest

Particle Board Studied at Syracuse

A study concerned with the physical properties of particle boards and instrumentation to measure these properties is now under way at the State University College of Forestry at Syracuse University, Syracuse, N.Y., announced Dr. Edwin C. Jahn, associate dean.

To finance the 11-month project, The Borden Chemical Company of Bainbridge, N. Y. and New York City has granted the College of Forestry $2500 for fundamental research on particle boards.

The project is being directed by Prof. Alfred H. Bishop, associate professor of wood products engineering. Appointed as The Borden Chemical Company Fellow is Fortunato I. Stanziale of 112 Haven Rd., Syracuse.

American Foresters to Celebrate 60th Year

Members of the forestry profession will celebrate sixty years of organized progress at the annual national meeting of the Society of American Foresters, scheduled for November 13–16 at the Sheraton–Park Hotel in Washington, D. C. The theme will be "Forestry's Expanding Horizons."

More than 1,000 foresters from the United States and Canada are expected. Some 70 papers will be presented at 12 different sessions on subjects ranging from forest tree genetics to wood technology.

The three keynote speakers will be: U. S. Forest Service Chief Richard E. McArdle, William C. Bramble, head of the Department of Forestry and Conservation at Purdue University, and William M. Bailey of International Paper Company.

North California Section Officers

The following section officers have been appointed for the Northern California section, according to a recent announcement received from the section chairman:

The officers are: Victor H. Clausen, chairman; Victor S. Roth, vice-chairman; Roderick E. Black, secretary–treasurer; Nickolas E. Poletika and Harvey H. Smith, trustees.

Panel of Speakers at Quality Control Conference, from left to right: Steven Blake, Paul Graham, Jack Saunders, Gordon Bullard, W. I. Kyle and Robert Snider.

Wood Industry Conference

"Quality Control in Production Woodworking" was the subject of one day industry-education meeting of the Forest Products Research Society, co-sponsored by the University of Massachusetts and the Vermont Bureau of Industrial Research, conducted on May 19 at Gardner, Mass. Approximately 126 management and production personnel from the northeastern woodworking industry gathered to learn of the practical methods, latest processes and techniques developed in production for increasing efficiency and reduction of production costs. After the meeting, plant tours were held at the Gardner plants of S. Bent & Brothers, Inc., Conant–Ball Company, and Heywood–Wakefield Company.

Speakers and their topics at the Conference were: Jack Saunders, A. G. Spalding Co., Chicopee, Mass., Panel Moderator,; Steven Blake, Behr–Manning Co., Troy, N.Y., "Sanding"; Paul Graham, Clinic of Wood, Newfane, Vt., "Machining"; Gordon Bullard, National Hardwood Lumber Association, "Lumber Procurement"; W. I. Kyle, E. I. duPont, "Finishing"; and Robert Snider, Franklin Glue Co., Columbus, Ohio, "Gluing".

Changes in ASTM Staff

The Board of Directors of the American Society for Testing Materials has announced that Raymond E. Hess, Associate Executive Secretary, has been named Acting Executive Secretary, and Robert J. Painter, Executive Secretary since 1952, is to be Consultant to the Executive Secretary. He will continue as Treasurer of ASTM, and will give concentrated attention to Long-Range Planning work. These changes are brought about by Mr. Painter's long continuing convalescence from several hip operations.

Wood Pole Institute Held for Utility Personnel

About 150 representatives of utility companies and the Rural Electrification Administration held a three-day conference on wood pole problems at Colorado State University, June 15–17.

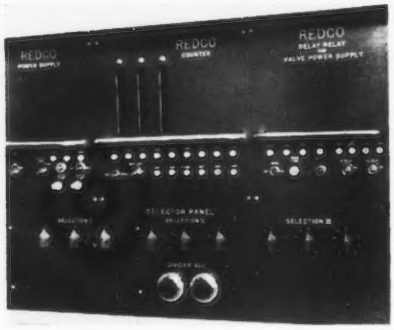
The Wood Pole Institute, one of 7 offered at land-grant colleges throughout the nation this year, was designed to give public and private utility personnel the information they need for proper installation, inspection and maintenance of wood pole lines.

Keynote speaker at the opening session was David E. Hamil, REA administrator and a former Colorado State representative from Logan County. Hamil pointed out the high replacement cost of wood poles used by utility companies and he emphasized the importance of making the poles last as long as possible.

The institute delegates also heard lectures dealing with the structures and properties of wood, the deterioration of wood and its prevention, pole specification characteristics and strength, and other wood problems.

Highlight of the meeting was the presentation of a trophy to Clarence H. Amadon, timber consultant for the Electric Engineering Division of the Rural Electrication Administration, second from left, for his pioneering role in the promotion of the use of lodgepole pine poles by utility companies. Presenting the trophy, right, is Harry Troxell of the CSU forestry staff and institute chairman. Looking on are John H. Rixse, assistant chief of the EE division of the REA, left; and George Q. Lumsden, timber products engineer for the Bell Telephone laboratories, Murrayhill, N. J..

NEW PRODUCTS and Literature



Variable-Speed Clipper Timer

A new variable-speed clipper timer for veneer production, accurate to within ¼ inch at any speed from zero to maximum, has been announced by Republic Electric & Development Co. of Seattle.

The clipper timer eliminates all electric eyes. A measuring wheel six inches in diameter rides on the veneer at the infeed side of the clipper, transmitting pulses to the counter every 1/10 inch of veneer. Curling edges or slippage of the veneer on the conveyor belts do not affect accuracy.

For complete information, write Republic Electric & Development Co., 2627 Western Avenue, Seattle 1, Washington.

Redwood Receives Weathering Tests

Lifecoat factory-primed redwood, without a final coat, indicated ability to withstand approximately 1 year of exposure without failure and, even after this exposure, was in excellent condition to receive a final coat, Simpson Redwood Company has announced.

Weathering tests were part of a series conducted for Simpson by Harlan Associates, San Francisco, a nationally-known paint testing laboratory.

Lifecoat redwood products also were tested for wicking, blister resistance, prime coat compatability with finish paints, water repellency, primer coat thickness, and ease of finishing.

Harold Harlan is shown examining a piece of factory-primed redwood being tested in this weatherometer.

New Compact Power Saw

A new compact, all-purpse power blade saw has been introduced by the Wright Saw division of Thomas Industries, Inc., Louisville, Ky. The gas operated, 19-pound GS2016 has a 16-inch cutting blade and only six moving parts. In the above picture, Mary Alice Fox, Miss Wisconsin of 1960, is testing the compact saw with the help of Gilbert Gusland, Merchandising Manager for Wright Saw (center), and Kenneth Hayes, Wright Saw Sales Manager (right).

June Housing Starts Low

The Census Bureau reports that housing starts in June totaled 125,200, compared to a revised figure of 127,500 in May. The June total represents a seasonally adjusted annual rate of 1,334,000 units, compared with the May rate of 1,336,000 units. However, "Housing Trends" pins a "Sagging Sixties" tag on the home building picture and makes this comment: "Our Washington observers predict new housing starts for all of 1960 will be off 25% unless the buying public gets an injection of buying confidence."

Meanwhile, the Commerce Department reports in its "Midyear Review" that private housing starts will hit an estimated 1,325,000 units—"assuming that the balance of 1960 will show a gradual rise over the seasonally adjusted annual rates for the first 5 months of the year, which averaged 1,298,000 units." Noting that "a more plentiful volume" of mortgage money is available, the Department says that a further improvement is anticipated next year. (Lumber Letter, July 24)

Wood Treatment Plant Built in Arizona

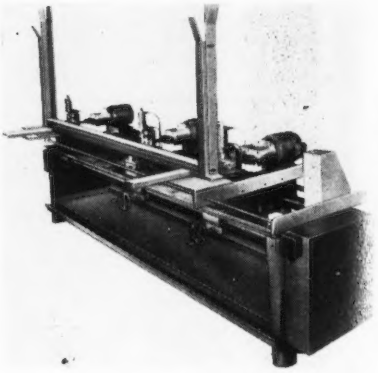
Construction of a $300,000 wood treatment plant by Southwest Forest Industries, Inc., will soon begin on land leased from the Yavapai Indian Tribe. The 32-acre site is on the Santa Fe Railway, approximately 1½ miles north of Prescott, Arizona.

J. B. Edens, President of Southwest Forest Industries, announced that actual construction of the plant will bring to fulfillment plans first formulated almost three years ago. Engineering and supervision will be done by the Taco Corporation of Spartanburg, South Carolina.

Mr. Edens has also announced that James A. Hutchison of Seattle, Wash., has been named resident and project engineer for construction of the firm's multimillion-dollar pulp and paper mill near Snowflake, Arizona.

Torsion Tear Tester Bulletin

The Albert Torsion Tear Tester was developed to measure shear strength or tearing resistance of strongly directional materials which are difficult to measure by other test methods. Reinforced shipping tape, corrugated boxboard, textiles, highly calendered rubber stocks, etc. usually tear at right angles to the direction of greatest strength. The Albert Torsion Tear Tester insures a measurement not procurable in any other way. Bulletin 265 describes the instrument and the method of operation as well as giving typical applications.



Multiple Drilling Machines

A complete line of custom engineered multiple drilling machines incorporating some of the most advanced and progressive design features in the industry today has been introduced by Pistorius Machine Company of Hicksville, New York. Ruggedly built of heavy cast iron to withstand high speed continuous operation, these drilling machines are designed with central pneumatic drives which feed all drilling stations simultaneously, eliminating unnecessary hoses, and greatly simplifying operation.

Complete specifications listed in Bulletin No. MD 1596 available from the Pistorius Machine Co., Dept. *FPJ* 3 Burns Avenue, Hicksville, New York.

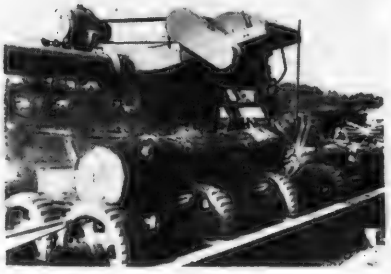
U. S. Plywood to Take New Medco Output

Alger Chaney, president of Medford Corporation, and Gene C. Brewer, U.S. Plywood president, have revealed that Medco, a pioneer lumber company headquartered in Chicago, is entering the plywood field for the first time with construction of a plant at Medford, Oregon. When completed in early 1961 it will be "the most efficient in the industry," the executive said. U. S. Plywood's engineering and operating know-how are helping to launch the plant which is designed for an output of 7,000,000 square feet of fir plywood monthly.

Fred Isley has been appointed public relations director of U.S. Plywood, S. W. Antoville, board chairman and chief executive officer, has announced. Isley was formerly with Carl Byoir & Associates, public relations counsel and the Dairymen's League Cooperative Assn., Inc. in New York.

Truck Cranes Show Strength

The world's largest truck crane had no trouble lifting a "little brother" machine of the same type 100 feet off the ground, in a recent demonstration of P&H equipment manufactured by Harnischfeger Corp. of Milwaukee. In routine operation the proud bruiser can wield a 200-foot boom plus a 50-foot extension, and also can lift up to 80 tons with no strain. The junior member of the family is known as the "Miti-Mite" because it boasts more operating flexibility than any other truck crane of any size—including big brother. Weighing in at a mere 31,000 pounds, little Junior can wield a 70-foot boom plus a 20-foot extension and can toss around loads up to 25,000 pounds. Both machines were bought by John N. Brocklesby Transport Ltd. of Montreal. Free literature is available from Harnischfeger Corp., 4444 W. National Ave., Milwaukee 46, Wis.



Soderhamn Introduces New DC-8 Heavy Duty Barker

Described as a massive West Coast type machine, Soderhamn's new DC–8 handles logs from 6" to 60" dia., 6' to 28' in length. It is also available in a larger model for logs 12" to 80" diameter. The new machine is built for extremely rugged conditions and uses extra heavy duty bull wheels, reversible and variable in speed, on 15/16" shafts and bearings, driven by 10 HP electric motor. The barker uses shaver, scraper, or flail head, powered by a 50 HP motor. A hydraulic unit controls speed and movement of barking head as well as the built-in log kicker.

Booklet Describes New Resin

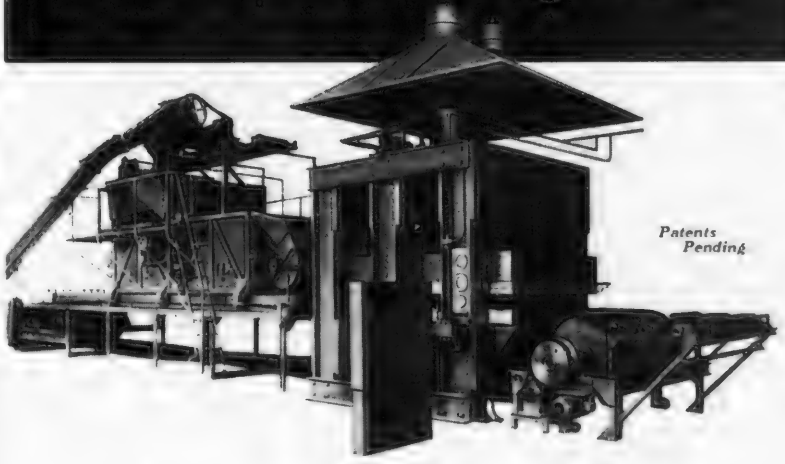
Technical data on National Starch and Chemical Corporation's new polyvinylidene chloride latex, Resyn 3600, has been compiled into a special booklet (Technical Bulletin 340) available from the company's Resin Division, 750 Third Avenue, New York 17, N.Y. Bulletin 340 describes the physical and chemical properties of Resyn 3600, both in latex and film forms. It also specifies degrees of resistance to water vapor and common gases at varying film thicknesses (along with comparative data on polytheylene films); formulating information; chemical resistance data; status of Government approvals for food packagings applications; recommended techniques for coating and handling.

Glue Bonds Hardboard Without Sanding

A new glue combination for cold press bonding hardboard to various wood surfaces without the need for sanding has been specially developed for the cabinet and furniture industry by National Casein Company, Chicago.

The new combination consists of National Casein Company's No. 30 powdered casein glue which is mixed with water. After mixing, LG–40, a special formulation, is added. The resulting liquid glue can be used in cold press work, will set rapidly but also give adequate setting time, and costs less than 10¢ per pound. In addition, it has excellent working life and is easy to clean up.

Flakes into Flakeboard with the Bison System



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Latin American Forests Examined

The need for expanding the controlled and rational use of Latin America's forest resources was the main theme of the 7th session of the Latin American Forestry Commission which was held in Mexico City, August 3–5.

Working papers prepared for the meeting by the FAO secretariat show that the production of industrial wood in the entire region is less than that of Sweden. They mention that much more wood is being lost annually through fires, pests and uncontrolled agriculture than is being extracted for fuel and industrial use. These papers point out that controlled use of Latin America's vast forest resources is gradually becoming a part of planned economic development; however, the results are still considered pitifully small compared with the potential.

Oregon Center Gets Grant For Douglas-fir Studies

Study of reasons why Douglas-fir is hard to establish on south slopes and other troublesome areas in western Oregon will be speeded by a grant of $7,200 from the National Science Foundation in Washington, according to Dale Bever, Director of research on forest lands at the Oregon Forest Research Center in Corvallis.

Work will be done cooperatively under direction of Dr. Ernest Wright, research pathologist of the Oregon Forest Research Center, and Dr. Walter B. Bollen, soil bacteriologist of Oregon State College.

The study is aimed at learning how symbiotic fungi that aid growth of seedlings are affected by southern exposure, depth in soil, seasonal changes in weather, and burning to slash.

California, Oregon Study Sawmill Markets

Marketing practices of west coast sawmills are to be studied in separate projects by researchers from the University of California's School of Forestry in Berkeley and Oregon State College.

At California, the researchers will investigate pine lumber marketing practices of sawmills in El Dorado, Placer and Nevada counties in order to discover the causes of the instability which has characterized the region's important lumber industry in the past, reports U. C. forestry Dean Henry J. Vaux. Dr. John A. Zivnuska, professor of forestry and a nationally-recognized authority in the field, will direct this study.

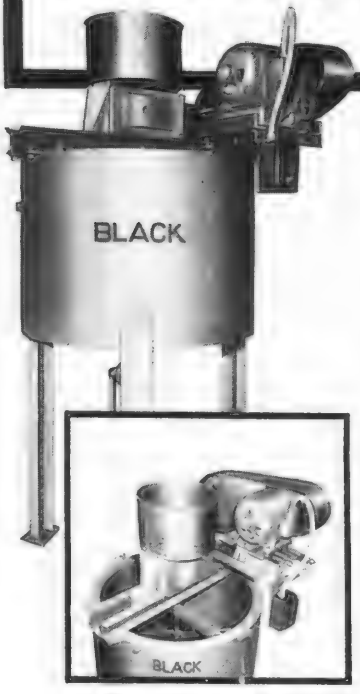
Approximately 300 sawmills in western Oregon will be studied by Oregon State College. The project will assess current marketing practices and obtain the industry's suggestions for improvement of log and lumber markets. Charles F. Sutherland of the school of forestry staff and Emmy Thompson, graduate assistant, will conduct the study.

Both of these investigations are part of a joint regional marketing project which includes sawmills in Washington, Idaho, Colorado, Utah and New Mexico as well.

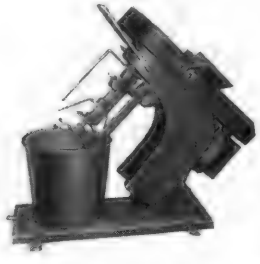
THE BLACK BROTHERS

Cold Glue Mixers

FOR POWDERED OR LIQUID ADHESIVES



The Black Brothers stationary cold glue mixers are made in a full range of capacities from 10 to 500 gallons. They are the result of expert engineering combined with years of practical experience in glue equipment manufacturing. Their many features include: (1) Sifter for glue powder (2) *Double agitators which give a beating action resulting in the smoothest possible mixture in the least possible time* . . . see close-up on left (3) Pressure lubrication (4) Cut steel gears . . . hardened and lapped (5) Large quick-acting valve at bottom. Optional equipment includes (1) water jacket (2) variable speed drive. For full information write today for Bulletin 11-1.



The Black Brothers portable motor driven cold glue mixer is made in 2, 5, 7½, and 15 gallon sizes. It has a number of exclusive Black Brothers features such as glue powder sifter, two-way agitation, and specially shaped flat paddles to give a beating action to the agitator. In addition this mixer has a hinged arm that swings up to allow the pail to be inserted or removed. Write for Supplement to Bulletin 11-1.

"If it Is Gluing Equipment—We Have It"

THE BLACK BROTHERS CO., INC.—Mendota 8, Ill.

Since 1882

WCLA Publishes New Grades and Uses Book

Detailed information on the GRADES, USES and SPECIFICATIONS of West Coast lumber is available in West Coast Lumbermen's Association's new 20-page booklet. The species of the Douglas Fir Region—Douglas fir, West Coast hemlock, Western red cedar, Sitka spruce and White fir—are covered at length, with descriptions and photographs of typical grades and patterns of finish lumber, siding, boards, framing, joists and planks. Conversion tables are included for both construction and finish lumber, giving the conversion from FBM to square footage and lineal footage to FBM.

Lumber Manufacturers Offered 5-Year Loans

A new, long-term financing plan for growth companies in the lumber industry has been announced by Mercantile Discount Corporation, Chicago. Loans of $[illegible]000 to $2 million will be available for terms up to five years. Robert B. Scott, president of Mercantile Discount, indicated that the plan has been used for three years in the lumber industry, but tight money prevented the company from announcing it widely.

"Extensive experience with growth companies in the lumber industry shows that short-term money is not the answer to their problems. Five-year capital loans involving no share of ownership or profit have worked out to be the best solution.

Applications for such 5-year financing will be processed at the company's headquarters: 110 South Dearborn Street, Chicago 3, Illinois.

What's New in *Technical Publications*

Single Copies of the Following Reports Available Free Upon Request from the rector, U.S. Forest Products Laboratory, dison 5, Wis.

Two new reports, one describing the milling industry in Hawaii and the ier giving the properties of five native waiian woods, are among nine new or ised reports recently issued by the U.S. est Products Laboratory here.

In **Report 2190, 'Factors Influencing . . Expanded Sawmilling Industry for Hawaii,"** some of the problems involving logging operations in Hawaii are analyzed. In it certain factors are examined that are expected to influence the development of sawmilling there. The report also contains suggestions for equipment, plant layout, and related items that may be best suited to handle Hawaiian timbers.

Another report, entitled **"Physical, Mechanical, and Other Properties of Five Hawaiian Woods," Report 2191,** presents the results of research involving strength and related properties of five species, ohia, eucalyptus, shamel ash, Australian redcedar, and redwood, that grow in Hawaii. The report also contains results of an exploratory study of the veneer slicing and drying characteristics of ohia and eucalyptus.

In **Report 2192, "Modified Woods,"** are described various chemical, thermal, and compression treatments used to modify the properties of wood. The properties and uses of some modified woods are also presented in the report.

Information on new developments in exterior natural finishes and in wood preservatives has been incorporated into the revised report entitled **"Making Log Cabins Endure," No. 982.**

Report 1769-27, "Method of Calculating Shrinkage or Swelling of Wood with Change in Moisture Content," is the most recent addition to the series, News and Views of this Kiln Drying Business." Included in the report are shrinkage values of wood based on its dimensions when green for many of the more common softwoods and hardwoods found in the United States.

A report entitled, **"Torsion of Sandwich Panels of Trapezoidal, Triangular, and Rectangular Cross Sections," No. 1874,** presents the mathematical computations for a theoretical analysis made of the torsion of a sandwich panel with a trapezoidal cross section as used in aircraft design.

Report 513, "List of Publications on Glue, Glued Products, and Veneer," date as of May 1960.

Recent developments in moisture-retardant finishes used to reduce shrinking and swelling and the accompanying stresses in wood that cause warping, checking, and weathering, are presented in **Technical Note 181, "Coatings for Minimizing Changes in the Moisture Content of Wood."**

Get More From Wood Waste....

...MORE HEAT, more economy, if you burn it

...MORE PROFIT, lower costs, if you sell it

WILLIAMS "No-Nife" HOGS

When used for fuel, wood scrap reduced to chips in a Williams Hog produces maximum heat . . . burns evenly . . . won't restrict flow of air . . . keeps smoke at a minimum. Handling costs are reduced as much as 75%!

When processed for sale as particle board chips, or as sawdust or wood flour, a Williams Hog produces a better quality, more uniform product . . . increases output . . . requires less labor . . . keeps power and maintenance costs low.

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OLDEST AND LARGEST MANUFACTURER OF HAMMER MILLS IN THE WORLD

Product Identifications Eliminated

A new policy respecting the publication of grade trademarks and other product identifications in Commercial Standards issued by the U. S. Department of Commerce was announced today by John C. Green, Director of the Office of Technical Services, Business and Defense Services Administration, of the Department.

The new policy will eliminate from published Commercial Standards any reference to trade associations, industrial firms or other organizations in the identifying marks used to designate products covered by or complying with such Standards.

Bibliographies Published

Eight Selective Bibliographies, listing the latest Government research reports and other technical documents available to science and industry, have been published by the Office of Technical Services, Business and Defense Services Administration, U. S. Department of Commerce.

Publications listed in the bibliographies cover such topics as food preservation, welding techniques, corrosion control, reliability and quality control in electronic equipment, linear programming, developments in adhesives, wood research, and studies of rare earth elements.

Design Manual Announced

The National Wooden Box Association announces the publication of a guide to lower handling costs in industry and agriculture. The publication, entitled BIN BOXES, resulted from numerous requests for an authoritative manual covering the economics, design considerations, material requirements, types and features of unit load containers.

The 12-page brochure contains information on important factors to be considered in the design of effective high-capacity handling containers. Its purpose is to provide a concise presentation of current data for the benefit of bin box users and manufacturers.

EMPLOYMENT Opportunities

Positions Offered

E-399—Teaching-research position in wood products in accredited forestry school in Midwest University. Teaching during one semester only in wood technology, seasoning, and preservation. Full-time research during one semester and summer. Appointment probably as assistant professor, but rank and salary commensurate with training and experience. (August)

E-401 Mid-West company is seeking a consultant organization or an individual or several individuals to take on a new product (folding doors) line. Desire a man to take the product from the detailed engineering drawing stage through the finished product. Will furnish him with detailed drawings and set up specifications. Present facilities at his disposal. Will also furnish an estimate of projected volume. (Sept.)

Employment Wanted

612—1956 graduate of the New York State College of Forestry with B.S. in wood products engineering field available for employment June 1, 1960. Major was wood utilization with courses in production management, finishing, and personnel relations. Experience in wood products industries. Age 25; married. (Sept.)

616—General foreman, superintendent, or quality control manager position desired by graduate in Wood Utilization with B.S. degree from Iowa State College. Two years' experience in quality control and production. Familiar with lab testing, millroom equipment and procedures. Age 26, married, 1 child. (August)

617—Engineer, Mechanical and Industrial, with wide experience in Woodworking and Finishing. Recent experience with particle board and polyester finishing seeks a managerial position (Sept.)

618—Quality Control or Product Development wanted by Wood Technologist with B.S. degree. Four years' experience in glued laminated timbers and four years' experience in plywood R. & D. Age 33, married, with 4 children. (Sept.)

619—Wood Technologist with 8 years' experience in research, production, and forest land evaluation in Southeast with company producing sewing machine cabinets. Desire like position with company with a future. B.S. in General Forestry and M.F. in Wood Technology. Prefer East and South. Age 38, married, one child. Resume on request. (Sept.)

620—Plant Superintendent—12 years' experience in production management and industrial engineering in furniture (case goods) and dimension plants. University graduate with B.S. in Wood Technology. Knows machines, all phases production, costs, incentives, layout, etc. Desire position as plant superintendent or equal. Age 34. Prefer Mid-South location. (Sept.)

POSITION WANTED

FINISHING PLANT—GENERAL MANAGER

Plywood Finishing — Printed or Natural. Quality finishes. Production Line basis. Can Design and operate new or existing plant. Train personnel. Inventive. Sincere. Cost Conscious. Available immediately. 25 years Wood Finishing experience. Widely known. References.

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NAMES in the NEWS

Richard D. Lane of the Washington D. C. office of the Forest Service, has been named Director of the Central States Forest Experiment Station in Columbus, Ohio. He succeeds **William G. McGinnies,** Director of the Station since 1953, who is retiring from the Forest Service after 30 years. He has been appointed Director of the Tree Ring Laboratory and Coordinator of the Arid Land Research Program at the University of Arizona in Tucson.

Kenneth Hayes has been named sales manager of the Wright Saw Division of Thomas Industries, Inc., according to an announcement made by **Thomas Fuller,** vice president, general sales, for Thomas Industries.

Joseph E. Barger and **James W. Peters** are announced as district representatives for the Pop Rivet Division of United Shoe Machinery Corp., Shelton, Conn., according to the company. Barger will cover the South Atlantic region and Peters, northern California.

J. C. Liebhart, Director of Purchases for the Drexel Furniture Co., and **R. B. Johnston,** President of American Furniture Co., were re-elected to serve as chairman and vice chairman respectively, of the North Carolina Forestry Association's Furniture, Plywood and Veneer Council at its annual May meeting in Raleigh, N. C.

Edwin O. Thompson has been named manager of the Washington office of the West Coast Lumberman's Association and the West Coast Lumber Inspection Bureau. Thompson, a 29-year veteran in the lumber industry, succeeds the late Cecil A. Luce, who served in the Washington post for 15 years.

Mortimer B. Doyle, executive vice president of NLMA, has been appointed to the Association Committee of the U. S. Chamber of Commerce. The committee advises the Chamber's Board of Directors in the development of activities and services aimed at increasing the effectiveness of trade and professional associations.

Appointment of **E. Joseph Maragni** to the position of assistant controller for domestic operations of The Borden Chemical Co., and of **Richard Lenz** to the position of assistant controller for international operations of The Borden Chemical Company, has been announced by **Joseph R. Dill,** controller.

Three executives have been named to key posts at Fiddes-Moore & Company, it has been announced by **William R. Ritchie,** president of the firm which is a subsidiary of Evans Products Company of Plymouth, Mich. **Emory Moore,** a vice president of Fiddes-Moore, has been named executive vice president of the subsidiary company. Appointed a vice president and assistant secretary is **Bruce Mallery,** formerly in charge of plywood purchases for the company. **Bruce Fulton,** former assistant general manager of the parent company's Western Division, has been named a vice president and assistant treasurer.

Recipients of fellowships for advanced study and research in forestry for 1960-61 at the University of California have been announced by Forestry Dean **Henry J. Vaux.** They are **Joe B. Zaerr,** who has been given the $1,800 W. S. Rosencrans Fellowship in Forestry for his studies in plant physiology; **Don Minore,** research worker at the U. S. Forest Service's Pacific Northeast Forest and Range Experiment Station, who has received the $1,700 Baker Research Fellowship for work on his Ph.D. in botany; and **Norman E. Johnson,** project leader in forest entomology research with the Weyerhaeuser Company, who was awarded the $2,000 Hilgard Scholarship to continue studies toward a Ph.D. in entomology.

Dean Emeritus **Joseph S. Illick** and Professor Emeritus **Nelson C. Brown,** member of the faculty emeritus of the State University College of Forestry at Syracuse, have been honored by the Northeastern Loggers' Association at the sixth annual Northeastern Loggers' Conference held recently at Utica, N. Y. Both men received Distinguished Service Plaques "for distinguished service in forestry practice and education" during their long careers of service.

Section 8—Inside Stadium
University of Washington, Seattle

Mill Equipment, Inc.

FPRS FOREST PRODUCTS JOURNAL VOL. X, NO. 8 AUGUST, 1960

NEW TECHNIQUE FOR EVALUATING

Show-Through of Particle Board Cores[1]

B. G. HEEBINK

Forest Products Laboratory,[2] Forest Service,
U. S. Department of Agriculture

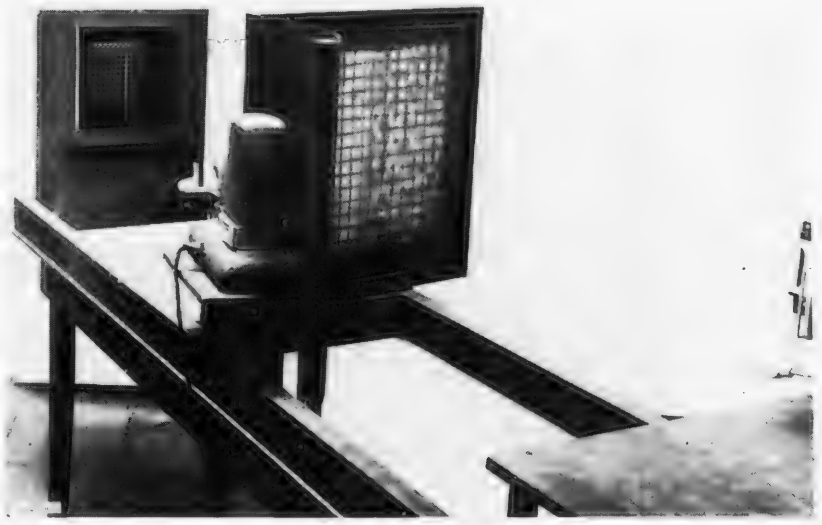


Fig. 2.—Show-through comparator apparatus: projected grid on panel is 9 inches squares. Note difference in square pattern on screen produced by exposing panel halves to conditions of 30 and 80 percent relative humidity.

A new technique for comparing show-through of core stock and evaluating many of the variables that influence core fabrication. Its use has uncovered promising leads for commercial development work to improve utility and marketability of particle board.

CURRENTLY, ONE OF THE LARGEST outlets for particle board in the United States is for furniture core stock. Furthermore, until a major breakthrough is achieved in reducing the price and in producing a board suitable for exterior service, furniture core stock, along with underlayment and interior paneling, is likely to remain at the head of the list. Although these three outlets represent a large percentage of the particle board manufactured, their sum is only a minor percentage of the total footage of wood-panel materials used. The major portion is still plywood or lumber core. Undoubtedly, cost was one factor that accounted for this proportioning of the market in the past; however, particle boards are consistently dropping in cost whereas, due to the increasing scarcity of suitable veneers and lumber, the cost of plywood and lumber cores can be expected to remain constant or possibly to increase.

If costs are now in favor of particle board, why then has the particle board industry succeeded in capturing only a relatively small portion of the market for which it was primarily designed? With appropriate respect for characteristics such as dimensional stability, density, the need for a good edge, screw-holding capacity, and so forth, perhaps the most important single negative characteristic is that of show-through (commonly called telegraphing). The characteristic show-through pattern of particle board cores, which is noticeably different from that of plywood or lumber cores, is a vital consideration in the resistance to its wider use, particularly in the higher-priced furniture field. Conservative manufacturers of high-quality furniture are therefore justifiably hesitant about changing from high-quality plywood or lumber cores to particle board cores in spite of a favorable price differential.

The Author: Bruce G. Heebink, a frequent contributor to the Journal, is well known for his work on flooring, paper overlaid lumber and plywood, and particle board. A University of Wisconsin graduate in mechanical engineering, he has been with the USFPL since 1934.

[1] Presented at Session XVIII, Wood Composition Board, FPRS 14th Annual Meeting, June 9, 1960, in Montreal, Canada; approved copy received by the Journal July 7, 1960.

[2] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

Many researchers have attempted to evaluate the characteristic show-through pattern of particle board, the differences in these patterns as associated with board variables, and the difference between these patterns and those resulting from the use of all-veneer plywood or lumber-core plywood. Often the characteristic differences in these patterns are quite obvious to the eye, particularly in low-angle reflected light, but they are exceedingly difficult to measure, evaluate, and record. There is no standard method of evaluation available so each researcher has used his own technique, designed to fit his particular needs. Means such as high-magnification profiling devices, low-angle reflection of a standard line or grid pattern, reflection of lines of light, and merely visual inspection have been used. None has been entirely satisfactory. The profiler measures the deviation of a traced line on the surface from a straight line (which may have little relation to the general acceptance of the surface); the reflection of a standardized pattern depends largely on the glossiness of the surface; other methods involve no

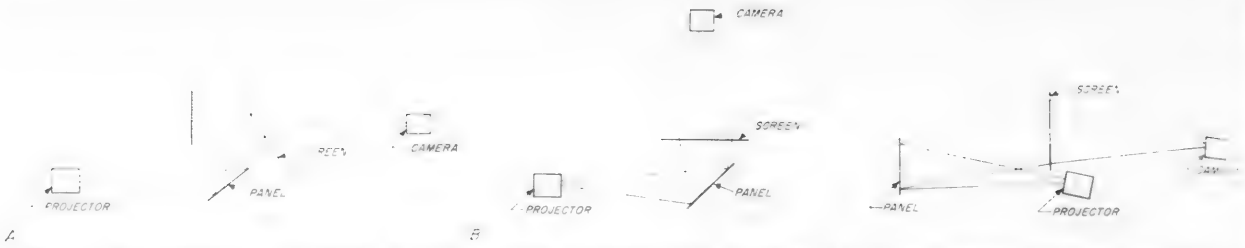


Fig. 1.—Three exploratory arrangements of projector, panel, translucent screen, and camera: A, Low angle projection on panel, with screen at an angle; B, Projection at 45°, with screen normal to light lines; C, High-angle projection, with screen and camera positioned to produce square pattern.

means of actually measuring the waviness of the surface.

The work presented here gives "circumstantial evidence" related to show-through. To date, time has not permitted a more basic evaluation of the factors, which will undoubtedly require work with a microscope or some other approach.

Evaluation Techniques

The first problem was to develop a practical, reproducible, and significant evaluation technique for show-through. Previously used methods (officially reported in scientific papers or used at the Forest Products Laboratory) were studied and exploratory tests were made on the more promising procedure, including some suggested for this specific purpose.

Basically, the methods can be divided into two classes: (1) The light-reflective methods, and (2) profiling devices. The exploratory tests quickly revealed that chances were better of developing a reflective method than a profiling device in the time available, so primary emphasis was put on the reflective techniques. The technique chosen is shown in Figure 1-C. It was selected because the higher projection angle produced a more uniform evaluation pattern than did techniques 1-A and 1-B.

Again after several exploratory tests a standard evaluation grid composed of 15 white squares in each direction divided by black lines, about one-fourth the width of the white space, was chosen. This gives a screen pattern with 14 black lines in each of the two directions. Positive transparencies were made from photographs of this master grid and mounted between glass in the usual manner of preparing glass-mounted 2- by 2-inch projection slides. Since these grids are accurately made, and the panels are positioned in exactly the same place each time they are photographed, it is possible to obtain a set of sequence photographs of any desired portion of the panel being evaluated. It is also possible, because the photographs are taken under carefully controlled standard conditions, to use them to make different comparisons among the many variables involved. The standardized apparatus used in this study is shown in Figure 2.

The next problem was one of choosing a uniform surfacing material that would be subject to little or no change with changing moisture conditions, and at the same time would be highly reflective and permit the use of standard assembly adhesives. Highly polished, selected thin birch veneer faces were tried and discarded because of the difficulty in reproducing the surface characteristics and the time involved in the finishing operation. Several thin plastic films were tried, but were found to be unsatisfactory, primarily because of susceptibility to wrinkling. Because decorative laminates are a common surfacing material for particle board cores, two or three varieties of this facing material were tried. The final choice was a high-gloss black laminate, 0.050 inch in thickness, accurately and uniformly sanded to exact caliper.

Attempts were than made to sharpen the reflected pattern of the grid by the use of some surface coating on the decorative laminate. It was found that a kerosene film, applied to the surface by wiping with a saturated rag, improved the reflection considerably without changing the character of the reflected pattern. It is important that all surfaces to be evaluated, such as decorative laminates and finished wood veneers be coated with a uniform film of kerosene. This can be done by wiping the surface with a lint-free rag that has been dipped in kerosene. The proper amount of kerosene to be used can be determined after a few trials. It should be enough to produce a high-gloss reflective surface but not enough to flow (and show flow lines) on the vertical surface. It will take a few seconds for the "wipe marks" to disappear from the surface, after which the surface is suitable for photographing for a matter of several minutes, before excessive drying produces a dull reflection.

Figure 3 shows the improvement produced by the use of the kerosene film on the right half of the panel. Subsequent tests have shown that, when the kerosene film is used on the

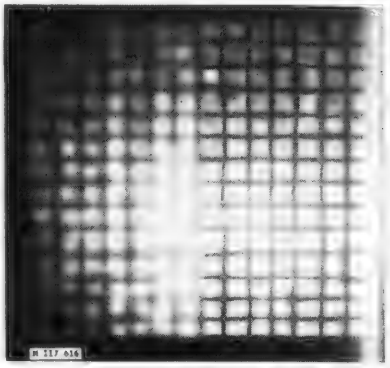
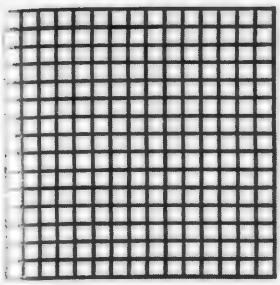


Fig. 3.—Grid reflection from panel, show improved clarity where kerosene was wi on the right half of the laminate.

surface of the decorative laminate, it makes little difference whether the laminate itself is patterned (such as a printed wood-grain pattern) or plain. This evaluation technique therefore shows promise of being usable on production panels regardless of the grain pattern or gloss of the decorative laminate.

To further justify the choice of a decorative laminate as a standard surfacing material, it was necessary to show that the distortion in the lines produced on the translucent screen were the result of variations in the particle board core (or the processing of the core in secondary gluing) and not due to changes in the decorative laminate. Figure 4 is presented to show the difference in the reflected pattern as associated with various surface characteristics. Figure 4 (upper left) is the master grid used in this evaluation. Figure 4 (upper right) is the reflection that results on the translucent screen when this master grid is projected, by means of the slide, onto a kerosene-wiped ground-glass surface (with one true reflective surface) with the projector focused to produce a sharp image on the translucent screen. This pattern, therefore, represents a near optimum surface.

Figure 4 (lower left) shows the reflection from the two halves of a high gloss black laminate, after a kerosene wipe. The left half was brought to equilibrium at 30 percent relative humidity, and the right half w



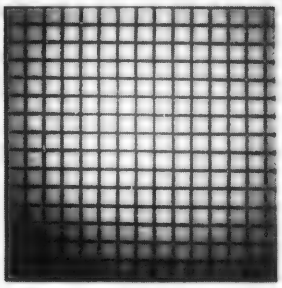
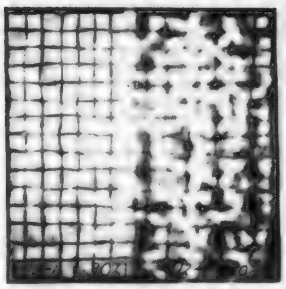
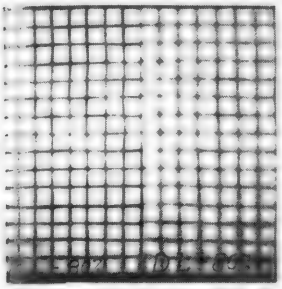
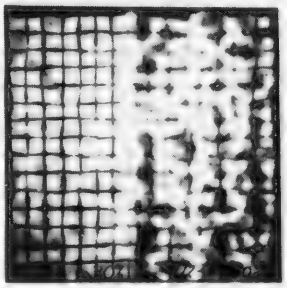
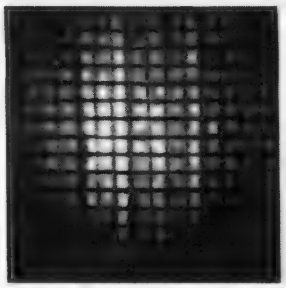


Fig. 4.—Sensitivity of the technique: top left, master grid; right reflection from the kerosene-wiped, ground glass surface; lower left, reflection from kerosene-wiped black laminate; right, reflection from test panel.









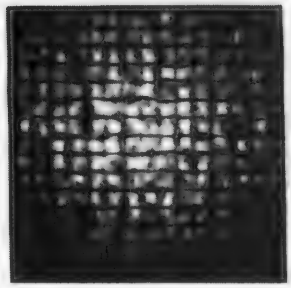


Fig. 5.—Versatility of technique: top left, standard core under black laminate; right, commercial particle board under black laminate; lower left, walnut veneer over crossbanded lumber core; right, walnut veneer over commercial particle board.

brought to equilibrium at 80 percent relative humidity. It may be noted that the difference between the 30 and 80 percent exposure conditions is one of a degree of fuzziness of the lines; in both cases, however, they are straight (within the limitations of holding the laminate to a flat plate by means of a vacuum).

Figure 4 (lower right) shows a typical reflected pattern from a Douglas-fir flake-type particle board (the standard base panel) after the left half had been exposed to 30 percent relative humidity and the right half to 80 percent relative humidity for 2 months (approximate equilibrium conditions). It is immediately obvious that the right half has much more distortion of the straight lines than the left half, although there is minor distortion of the lines in the left half also.

To evaluate the versatility of the technique, several panels made with different cores and different facing materials were photographed. Figure 5 shows four of these. The upper left is again the standard Douglas-fir flake-type particle board with the high-gloss black laminate, the left and right halves, respectively, having been exposed to 30 and 80 per cent relative humidity for 2 months. The upper right is a similar construction, but with a relatively high-quality commercial particle board as the core. The lower left is a typical, thick (1½-inch) lumber-core desk top with a yellow-poplar crossband on each side of the core and a thin black walnut veneer with a typical satin finish on the surface. The lower right has the same black walnut veneer and finish as the lower left, but the core is a commercial particle board. The latter 2 panels had been exposed to normal office conditions in Madison for about 4 years, and therefore should be typical of the surfaces on furniture after a few years of service. It is of interest to note that the technique used evaluates the surface irregularities due to show-through of the core regardless of the color or polish of the surface, within reasonable limits. This suggests the modification of the equipment so that it can be used as a portable apparatus to evaluate the surface of furniture as it leaves the factory or after known conditions of use.

Experience has shown that the following relationships exist among certain observed characteristics on the reflected grid pattern and the character of the reflecting surface:

1. Divergence of the grid lines accompanied by a dark spot at the center is produced by a slight bump or convex surface on the panel.

2. Convergence of the gird pattern associated with a light spot at the center indicates a dent or a slight concave surface on the panel.

3. A long, narrow light streak, with converging black lines, is produced by a long, concave furrow or depression in the surface (typical of the distortion of the surface over a lumber core or from a momentary stall of the panel in the sanding operation).

4. A long, dark streak associated with spreading of the grid is produced by a long, convex ripple on the surface, typical of distortion over a lumber core.

5. Distortions in the grid pattern are caused by angular displacement of the reflected light; therefore it is unlikely that these distortions can be interpreted in terms of depth of a depression or elevation of a bump.

Preparation of Test Panels

Exploratory Panels

A series of exploratory panels was made to determine the adequacy of the Forest Products Laboratory particleboard-making equipment for production of acceptable test panels, and to determine roughly the sensitivity of the show-through evaluation technique. The first series included three standard-sized boards (½ inch thick and roughly 24 by 28 inches in width and length), one from Douglas-fir planer shavings, one fromDouglas-fir 0.015-inch by 1-inch random-width flakes, and one from Douglas-fir slivers (made by hammermilling ½-inch-long pulpwood chips through a ¼-inch hammermill screen). Each of these boards was made to the following specifications:

1. Size: ½ by 24 by 28 inches (trimmed to 22 by 26 inches).
2. Particles: planer shavings, flakes, and slivers, fines (through 16-mesh screen) removed after drying.
3. Density: 40 pounds per cubic foot.

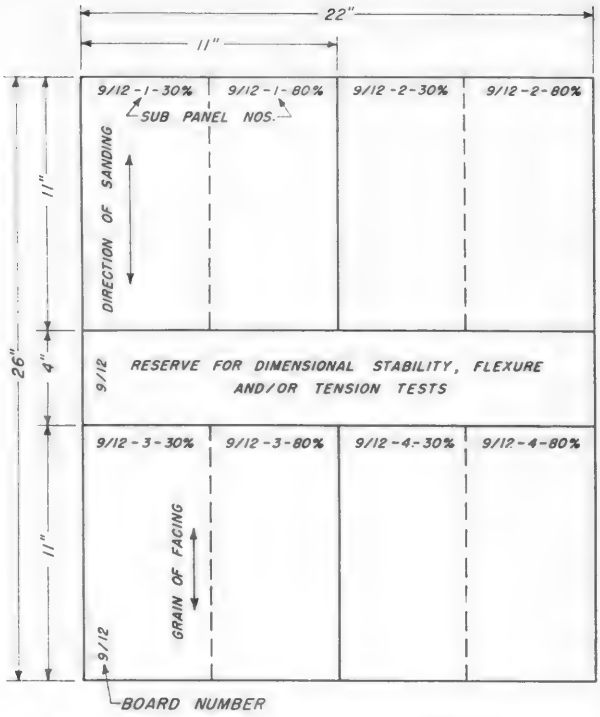


Fig. 6.—Cutting diagram used on test particle boards.

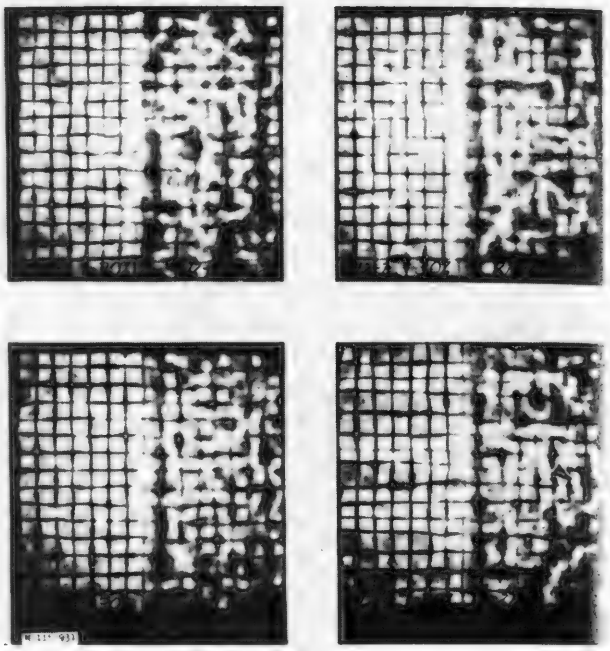


Fig. 7.—Standard flake-type particle board core; upper left pan sanded and assembled with no conditioning (at about 3 percent moi ture content); right, conditioned 2 weeks at 30 percent relative h midity before sanding and laminating; lower left panel condition 2 weeks at 80 percent relative humidity followed by 2 weeks at 3 percent relative humidity before sanding and laminating; righ brushed with water to produce a 6 percent moisture content, followe by 1 week at 30 percent relative humidity before sanding an laminating.

4. Moisture content of particles before spraying: 6 percent.
5. Resin: Liquid urea used without catalyst.
6. Resin content: 8 percent.
7. Moisture content of particles at time of pressing: about 12 percent.
8. Temperature of the press: 325° F.
9. Pressed to ½-inch stops (down on the stops in 3 to 4 minutes).
10. Time in the press: 15 minutes.

Each panel was marked and cut as shown in Figure 6. The 11-inch-square subpanels were then glued between two pieces of high-gloss black decorative laminate in a cold press at 50 pounds per square inch with a room-temperature-setting urea adhesive spread on the core only at the rate of 50 pounds per thousand square feet of glue line (wet spread). Subpanel 1 was sanded in a 2-drum traveling-bed sander (which removed about 0.030 inch from each side), and it was glued within 24 hours after the core was manufactured. Subpanel 2 was conditioned for 2 weeks at 30 percent relative humidity, then sanded and glued in a similar manner. Subpanel 3 was conditioned for 2 weeks at 80 percent relative humidity followed by 2 weeks at 30 percent relative humidity, and then sanded and glued. Subpanel 4 was treated with the proper amount of moisture on both surfaces to bring about (after diffusion) the equilibrium moisture content produced in the 30 percent relative humidity atmosphere. It was then conditioned between plate glass sheets for 2 weeks in the 30 percent relative humidity room, then sanded and glued.

Each subpanel was then cut in half (along the dotted lines shown in Figure 6) and the left half of each panel was stored for 2 months at 30 percent relative humidity, while the right half in each case was stored for 2 months at 80 percent relative humidity. After exposure, the halves were assembled next to each other in the evaluation apparatus and photographed.

Additional particle board panels of the Douglas-fir flake type (hereafter referred to as the standard board) were made to evaluate the effect of pressure, both in a cold press and in a hot press at 25, 50, 100, and 150 pounds per square inch. The room-temperature pressing was done with a typical room-temperature catalyzed urea, and the hot pressing with a typical intermediate-temperature melamine adhesive (cured at 250° F.).

A summary of the conclusions from these exploratory tests follows:

1. None of the surfaces are perfect (a perfect surface would result in straight lines in both directions).

2. In all cases the subpanel expose to 80 percent relative humidity showed more distortion than the subpanel ex posed to 30 percent relative humidity

3. In general, it appeared that the surface of panel No. 3 (exposed for 2 weeks at 80 percent relative humidity followed by 2 weeks at 30 percent relative humidity before laminating) was slightly better than panel Nos. 1 2, or 4.

4. The panel made from Douglas-fir flakes was somewhat smoother than the panels made from either shavings or slivers.

5. The evaluation method is exceed ingly sensitive.

6. The high-gloss black decorativ laminate appeared to be a satisfactor surfacing material.

7. In general, cold pressing resulte in better surfaces than hot pressing and the lower pressures used in col pressing appeared to be best.

First Series of Test Panels

Experimental Design: The firs step in designing this study was t list all of the variables thought to b important in causing show-through Because the variables are exceedingly numerous, it was found that the in vestigation of all of those listed, in all of the combinations, would require fabrication of about 6,000 particle boards. Since this was impracticable, it

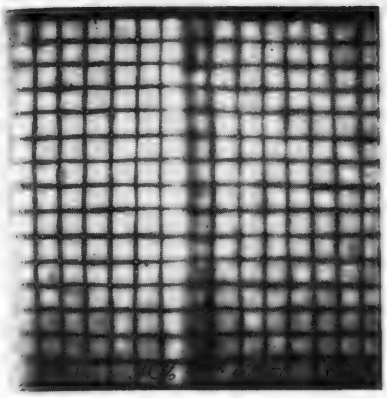


Fig. 8.—Improved surface resulting from e use of fines on both sides of standard fake board (unsanded back side shown; no preconditioning).

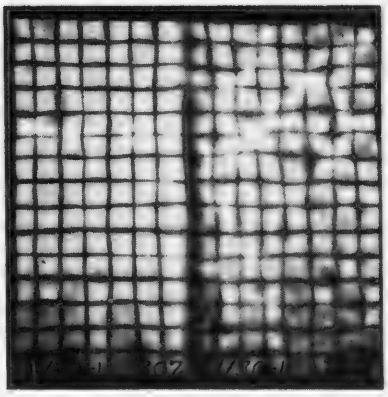


Fig. 9.—Sanded top face of panel shown in Figure 8 (no preconditioning).

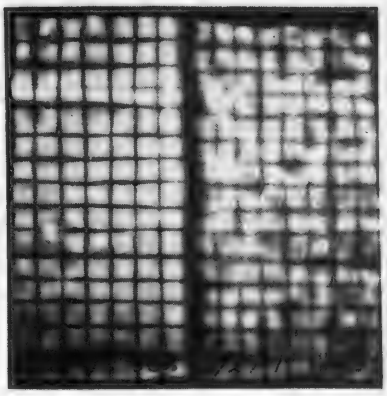


Fig. 10.—Sanded face, complete core made from flake fines (no preconditioning).

was decided to establish a standard board construction, typical of flake boards made from Douglas-fir, and then investigate individually the variables thought to be most important. There undoubtedly is interaction among some of the particle board fabrication variables, but to reduce the number of boards required to a workable number, the evaluation was undertaken on the assumption of no interaction. In reality, perhaps, this approach can be looked on as more of a screening test, a search for clues that can later be evaluated more conclusively. When this approach was followed, the initial number of particle boards required, with no replication, was only 20. Repeating the standard board three times to test the consistency of replication increased the initial number to 22.

The variables included in this first series of boards are listed below; items in italics designate standard boards.

1. Monogeneous boards
   - A. Particle shape and size
     - (1) Flakes (1 inch long, random width). Thickness: 0.007,*0.015,* and 0.027 inch.
     - (2) Slivers, ½-inch chips through ¼-inch hammermill screen.
     - (3) Planer shavings.
     - (4) Fines, through 16 mesh (from 0.014- by 1-inch flakes).
   - B. Species
     - (1) *Douglas-fir.*
     - (2) Aspen.
   - C. Resin content
     - (1) 4, *8,* and 12 percent.
   - D. Moisture content (at time of pressing)
     - (1) 8, *12,* and 16 percent.
     - (2) 8 percent in core with 20 percent in face (faces approximately 1/16 inch thick, ¼ of total weight).
   - E. Pressing of boards
     - (1) *Pressed to stops* (down on stops in 3 minutes).
     - (2) High prepress pressure (cold pressed to final board thickness).
     - (3) Rubber cauls both sides (no stops, constant pressure).
   - F. Density
     - (1) 35, *40,* and 45 pounds per cubic foot.
   - G. Thickness
     - (1) ¼ inch, *½ inch,* and ¾ inch.
2. Three-ply boards (1/16-inch-thick faces)
   - A. Fines faces on 0.015-inch by 1-inch flake core.
   - B. Fines faces on sliver core.
   - C. ¼-inch flakes (0.010 inch thick) faces on 0.015-inch by 1-inch flake core.

Fabrication of Test Panels: Following the manufacture of the particle board cores, each was cut, numbered, and processed as shown in Figure 6. The decorative laminate facings were conditioned at 30 percent relative humidity prior to assembly, and the assembly operation was done in a cold press at about 80° F. at 50 pounds per square inch for at least 4 hours, between aluminum cauls covered with a thin, uniform kraft paper. The subpanels, after being sawn in half, were then conditioned as before; one half at 30 percent relative humidity and the other half at 80 percent relative humidity for a period of 2 months.

This procedure permits the evaluation of each of the variables by the four conditioning treatments used previously, but includes only one pressing condition (room temperature at 50 p.s.i.). One other change in the procedure was the sanding of the top surface only to a depth of about 0.030 inch. The bottom surface remained as it was produced in the fabrication operation. Thus, the variable of sanding to a 0.030-inch depth versus no sanding could be evaluated on all of the panels, although the sanding was always on the top surface.

Results of Evaluation: After all the evaluation photographs were available, the photos that showed the four variables in assembly techniques for each panel were printed on one sheet. An attempt was made to arrange these prints in a progressive order, with those showing the most perfect pattern on one end, and those showing the most evidence of show-through on the other. This was done independently by three individuals experienced in reading the prints, and there was surprising general agreement in the three arrangements. It was relatively easy to pick out the five best and two worst patterns, but there was a large group of photographs, each representing a single variable, that fell in the center portion of the progressive ratings. The three replications of the standard board were almost identical and fell approximately in the middle of the order of perfection.

The following variables, taken individually and with no interaction assumed, seemed to have little or no effect on show-through, and produced grid patterns quite similar to the standard board shown in Figure 7.

Fines over slivers
0.007- or 0.015-inch-thick flakes
¼-, ½, or ¾-inch thickness of board
Aspen or Douglas-fir flakes
4, 8, or 12 percent resin content
35, 40, or 45 pounds per cubic foot density
8, 12, or 16 percent moisture content as pressed
Prepressing at 660 pounds per square inch
Shavings or standard flakes
20 percent moisture content on face flakes with 12 percent moisture content in the core

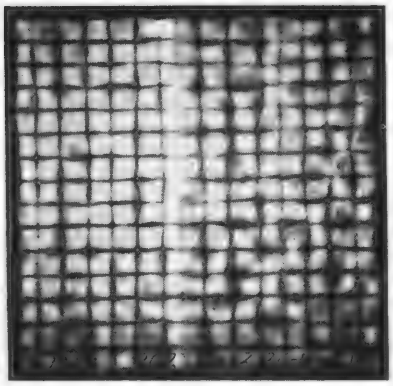


Fig. 11.—Effect of using ¼-inch rubber cauls in the pressing of the standard core. Core was sanded smooth after it was pressed (no preconditioning).

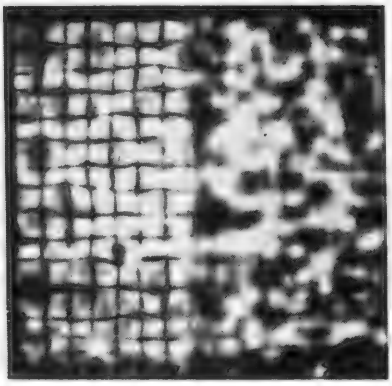


Fig. 12.—Surface produced by 0.027-inch-thick flakes in the core (no preconditioning).

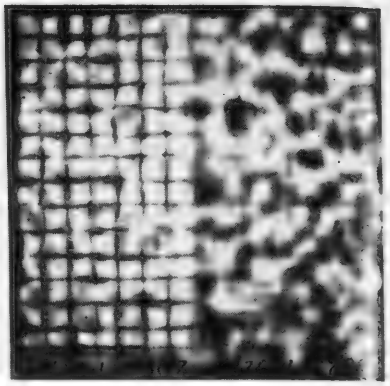


Fig. 13.—Surface pattern produced by sliver core (no preconditioning).

Those variables (in order) that showed the best grid pattern were:

Fines faces on flakes, unsanded back
Fines faces on flakes, sanded face
All fines, sanded face
Rubber cauls, sanded face
¼-inch flake faces, sanded face

Some of these are shown in Figures 8 to 11. Variables that produce the most imperfect grid pattern were:

0.027-inch-thick flakes, sanded face
Slivers, sanded face

These patterns are shown in Figures 12 and 13.

Trends from First Series of Panels: Definite conclusions are not justified from the limited number of boards and variables investigated. Certain trends are indicated, however, some of which appeared to be worthy of further investigation. Because the large group of variables, listed above, appeared to have little or no effect on the show-through pattern (as compared to the standard board) there was little to be gained by further evaluation of any of these variables, even in combinations. Furthermore, a tabulation of the difference in thickness between the halves of the panels exposed to 30 percent relative humidity and the matching halves exposed to 80 percent showed no relation between the average swelling in thickness of the panel and the quality of the show-through pattern. In fact, one of the best panels in the first series (fines on flakes) swelled more in thickness than many of the panels that had the most imperfect show-through patterns.

The addition of a surface layer of fines on a standard flake core, and the use of all fines, improved the quality of the surface only slightly at the original 30 percent condition, but the improvement was very pronounced after exposure to 80 percent relative humidity for 2 months. This suggested further pursuit of surface layers of fines of different types and thicknesses.

The rather surprising performance of the unsanded backs of some of the better-quality panels indicated that sanding (or lack of sanding) and type of sanding equipment should be explored. It further suggested that the sanding variables should be investigated on the top side of the board to determine whether the good performance of the sanded surface of the boards in the first series was because they were unsanded or because they were on the bottom of the board, which always had a somewhat finer texture, because of the sifting of fine particles to the bottom, than the top side of the board.

All of the panels investigated thus far had the standard decorative laminate glued directly to the core, with no crossbands. It would be of considerable interest to observe the effect of varying thicknesses and types of crossbands in subduing the show-through originating from the core.

The two species included, Douglas-fir and aspen, have quite similar volumetric shrinkage characteristics; therefore, it would be of interest to evaluate a third species of relatively low shrinkage, such as redwood.

Further, it would be advisable to include a grain orientation variable to determine the effect of edge-grain flakes as compared to flat-grain flakes, such as 0.015-inch-thick Douglas-fir at-grain and edge-grain flakes.

Finally, the question of the effect of reconditioning to the original 30 percent relative humidity on the show-through pattern should be determined. This could be done by re-exposing at 30 percent relative humidity some of the panel sections that had been conditioned at 80 percent relative humidity for 2 months.

Second Series of Test Panels

Additional Variables Included: A thorough study of the results of the first series of tests and consideration of additional suggested variables led to the selection of those thought to be most important for further study. A list of these panels that gives, in summary form, the construction and the treatment of the top surface of each follows.

TEST PANELS IN SECOND SERIES

Panel description	Top surface treatment (before or laminating to crossband)
Standard board[1]	No sanding
Standard board	Sanded
Standard board, special conditioning[2]	Sanded
Fines on top only	No sanding
Prepared fines on top only[3]	No sanding
Thick layer of fines on top only	No sanding
Thick layer of fines on top only	Sanded
Thick layer of fines on top only	Special sanding[4]
Aspen flakes (35 lbs. per cu. ft.), fines on top	No sanding
Redwood flakes	No sanding
Redwood flakes	Sanded
Redwood flakes (30 lbs. per cu. ft.), fines on top only	No sanding
Redwood flakes (30 lbs. per cu. ft.), prepared fines on top	No sanding
Aspen flakes (35 lbs. per cu. ft.)	No sanding
Aspen flakes (35 lbs. per cu. ft.)	Sanded
Aspen flakes (35 lbs. per cu. ft.)	Special sanding
Edge-grain Douglas-fir flakes	Sanded
Flat-grain Douglas-fir flakes	Sanded
Standard board plus 1/16-inch yellow-poplar crossband	Sanded
Standard board plus 1/16-inch red gum crossband	Sanded
Standard board plus 1/16-inch aspen crossband	Sanded
Standard board plus 1/14-inch Douglas-fir crossband	Sanded
Standard board plus 1/8-inch hardboard crossband	Sanded

[1]Standard board previously described.
[2]Core surfaces wetted to equivalent of 15 percent equilibrium moisture content, followed by conditioning 2 weeks at 65 percent relative humidity.
[3]Fines prepared by hammermilling 1-inch flakes to produce particles similar to the natural fines obtained from screening flakes over a 16-mesh screen.
[4]Sanded on a single oscillating drum sander with no felt between the steel drum and the paper.

The panels listed above as having fines on the top surface only require additional explanation. Normally, when fines or fine flakes are used on the surface of a particle board, they are used on both sides to balance the board properly. If, however, the fines are of a similar character to the core of the board, as an example, thin narrow flakes of approximately the same length as the thicker and wider flakes in the core, it should be possible

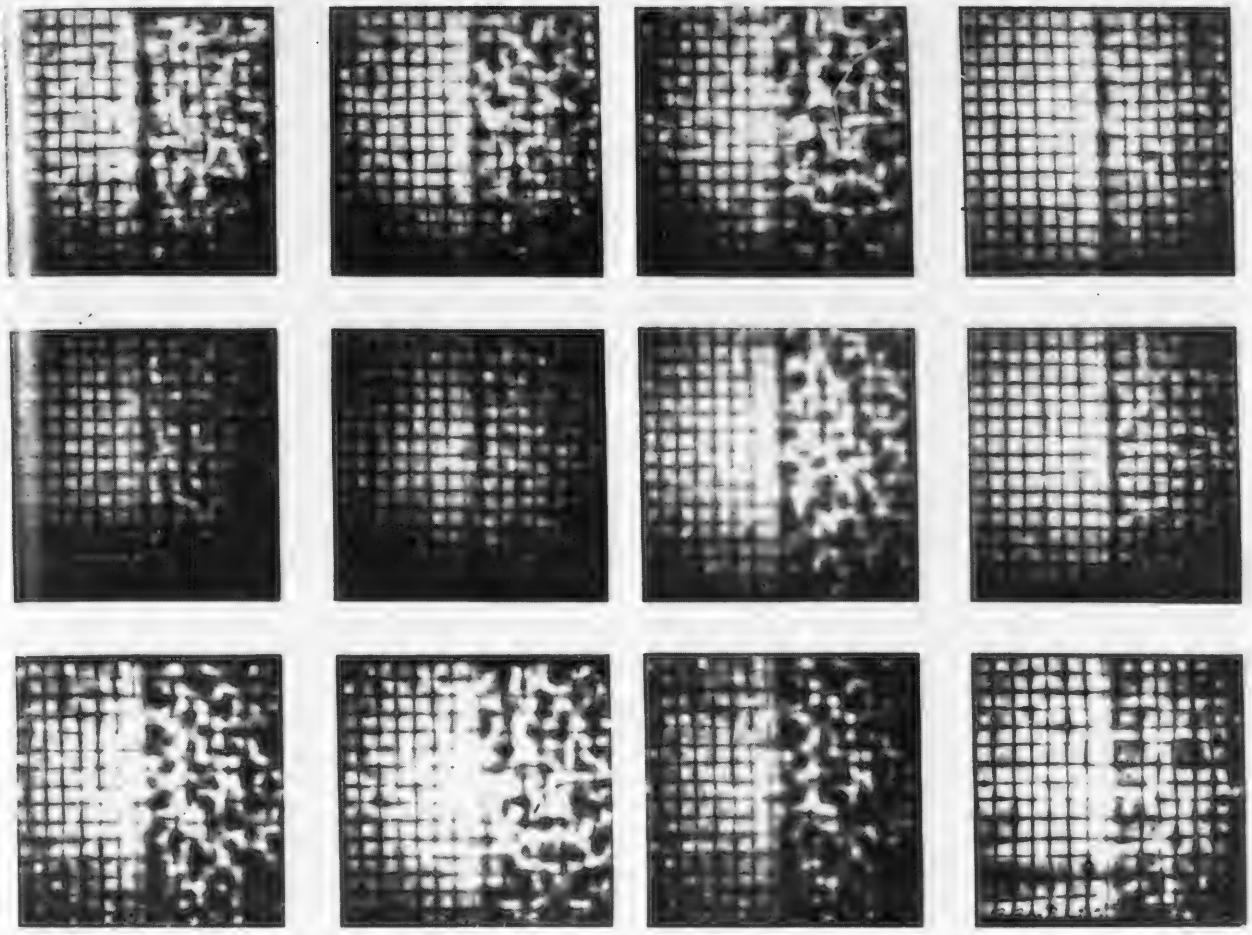


Fig. 14.—Effect of sanding with felt-cushioned sander drums. Left panels were sanded, whereas right panels were not sanded before they were laminated. Top, Douglas-fir flakes, center, redwood flakes, and bottom, aspen flakes.

Fig. 14–A.—Comparison of aspen flake boards and Douglas-fir flake boards overlaid with fines having 12 percent resin content: Top, no sanding; center, "microgrinder sanding;" and bottom, conventional felt-cushioned roll sanding.

to apply the fines layer to one side only without severe unbalance. This is based on the assumption that the dimensional stability of particle board is primarily a function of flake length, or possibly slenderness ratio of the particles, and that width and thickness are relatively unimportant.

Since the fines usually cost more per pound than the particles used in the core of a board, considerable savings could be achieved if the fines layer could be omitted from one side of the board, and further savings would result if the fines layer on the top of the board could be used without sanding. To evaluate this theory, the boards overlaid with fines were made in several constructions.

(1) A ½-inch thick board in which 1/16 inch on the top surface was composed of fines (⅛ of the weight of the board), intended to be used without sanding on the top.

(2) Same construction, but with *epared* fines (made by severe hammermilling of flakes) on the top only.

(3) Same as (2) only the layer of epared fines was ⅛ inch thick (¼ the weight of the board) designed to be used after sanding of the top surface.

It was realized that, even if boards of the above construction performed satisfactorily from a show-through standpoint, other characteristics such as a tendency to warp due to the slight unbalance, importance of eliminating precure of the unsanded top surface, and the necessity of keeping track of the top surface and specifying its use in furniture with this side up would require evaluation. The potential savings that might result from this construction would be achieved by reducing the amount of relatively expensive surfacing material and the possibility of using a planer as well as a sander to reduce the boards to the proper thickness tolerance, because material would be removed from the back side only.

Results of Test in Second Series: The boards in this series were evaluated as in the first series, except that only condition 1 (processed immediately after fabrication of the particle board) was employed in gluing the decorative laminates in place. This change permitted four matched 11-inch-square panels from each 24- by 28-inch particle board. The panels were photographed after the 2-month exposure period (the left half again at 30 percent and the right half at 80 percent relative humidity as before. For comparative purposes, these photographs were then combined to best compare the variables being studied.

Sanding Variables: The amount (depth) and type of sanding on the surface of a particle board core were found to have a measurable effect on the show-through pattern as evaluated by this technique. The standard sanding procedure used in the test reported here consisted of removing approximately 0.025 inch in one pass through a 2-drum, traveling-bed commercial sander with ½ and 00 paper on the first and second drums, respectively. Each drum had standard felt between the paper and the steel. Unfortunately, the machine was not adjusted properly during the sanding tests reported here; therefore, on occasions a slight groove or valley ap-

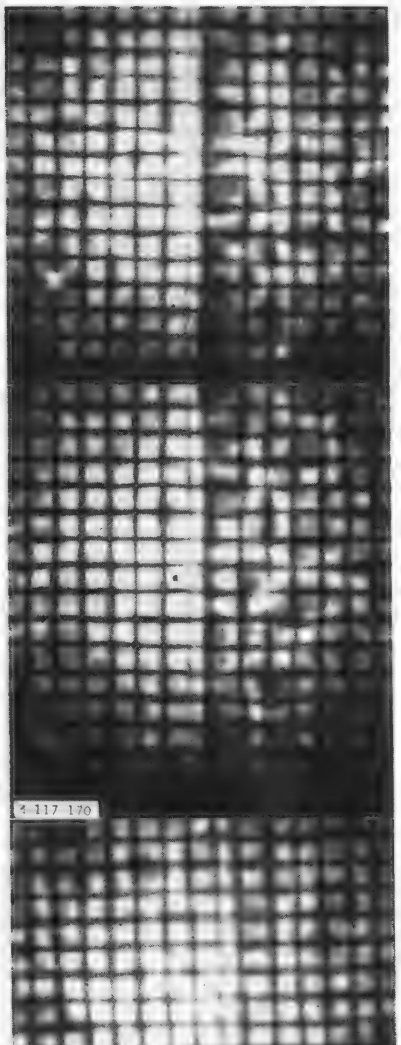


Fig. 15.—Effect of an unsanded 1/16-inch "fines" layer on top. Top panel, Douglas-fir; center, aspen; and bottom, redwood.

peared in the surface due to improper hold-down adjustment.

Figure 14 is a comparison of particle boards made from three species of flakes (Douglas-fir, redwood, and aspen). In each case the difference is shown between an unsanded and a sanded top surface under the standard decorative laminate. Again the left half of each panel was exposed at 30 percent relative humidity and the right half at 80 percent relative humidity for 2 months. As a general observation, the unsanded panels presented a better appearance than the sanded panels, particularly the halves exposed to 80 percent relative humidity.

A few exploratory tests on the effect of depth of sanding indicated that the deeper sanding produced a more prominent show-through pattern. This observation and the general character of the show-through pattern produced by sanding with felt-covered rolls suggest an association of show-through pattern with softness of the felt on the rolls. To explore the comparison of sanding rolls with felts between the paper and the steel drum versus the sandpaper directly on the steel drum (no cushion), a few panels were sanded on a single-roll "microgrinder" type of sander. Figure 14–A shows the comparison of aspen flake boards and Douglas-fir flake boards overlaid with fines (having 12 percent resin content) with no sanding (on the top), "microgrinder" sanding (in the center), and conventional felt cushioned roll sanding (on the bottom). There appears to be little or no difference between no sanding and "microgrinder" sanding, but sanding with the felt-cushioned rolls on both the aspen and the overlaid Douglas-fir board produced a more prominent, mottled show-through pattern.

Fines on the Surface: The effect of substituting the top 1/16 inch of a ½-inch standard flakeboard with fines (made by severe hammermilling of flakes) was evaluated on boards of Douglas-fir, aspen, and redwood. These were conditioned in the usual manner after the high-gloss black laminate was bonded to the unsanded surface of the board. The resultant show-through patterns of these three boards are shown in Figure 15. The improvement in the pattern was considerable, as compared to similar boards with no surface layer of fines. The relative improvement in the aspen board was greater than in either the Douglas-fir or the redwood board. The use of a fines surface layer on the aspen board produced a surface of equal quality to the fines surface layer on a Douglas-fir board.

In all three species, the most noticeable improvement was on the half that had been exposed to 80 percent relative humidity for 2 months, and of the three, the redwood board was again the best; there was little difference between the 30 and 80 percent relative exposure. In fact, this redwood board is the best of any of the boards made at the Forest Products Laboratory to date as far as show-through characteristics are concerned.

Grain Direction in Flakes: Standard Douglas-fir flakeboards were made with two grain orientations in the flakes—edge and flat. These flakes were produced from carefully selected blocks in which the grain angle was controlled to either essentially perpendicular to the knife travel (for edge grain) or essentially parallel to the knife travel(for flat grain). The blocks were from well-matched material so there should be little or no difference in the average density or growth characteristics of the material in the two groups.

Figure 16 shows the difference in the show-through pattern as associated with the two grain orientations in the flake. A noticeable difference can be observed in the respective patterns; the edge-grain flakes produced a higher quality surface than the flat-grain flakes. This at first appears somewhat contradictory because the measured thickness change in the panel made from flat-grain flakes (radial shrinkage) was less than half that of the panel made from edge-grain flakes (tangential shrinkage). There are, however, at least two logical explanations: (1) The distribution curve in thickness for the flat-grain flakes is considerably wider than the distribution curve for the edge-grain flakes. That is, the board from flat-grain flakes is made

Fig. 16.—Effect of grain orientation: top, flat-grain Douglas-fir flakes; bottom, edge-grain flakes. Both panels were sanded with felt-covered drums before they were laminated.

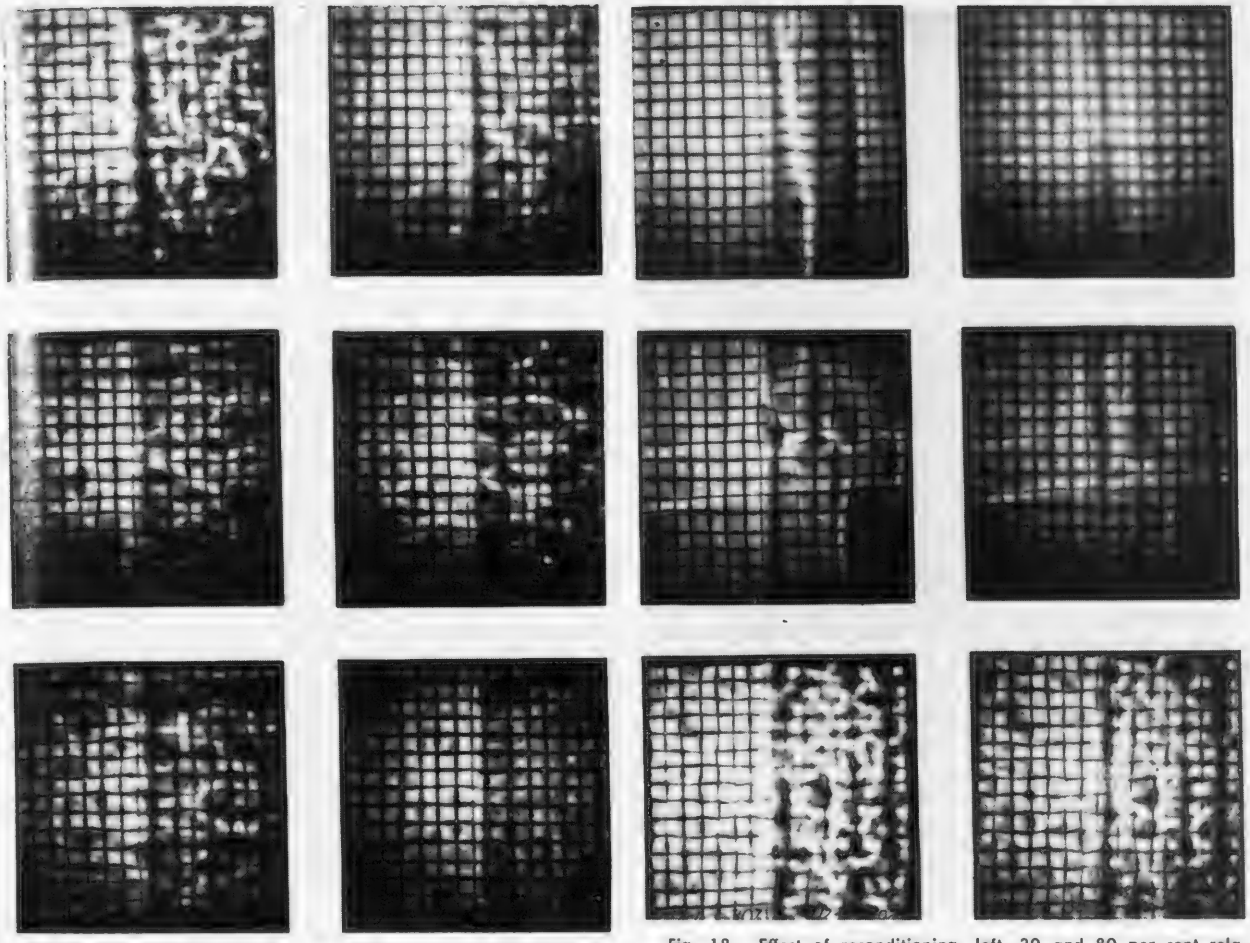


Fig. 17.—Effect of crossbands: upper left, no crossband; right, 1/16-inch yellow-poplar crossband; center left, 1/16-inch red gum crossband; right, 1/16-inch aspen crossband; lower left, 1/14-inch Douglas-fir crossband; and right, ⅛-inch hardboard crossband. All cores were sanded with felt-cushioned rolls before they were laminated.

Fig. 18.—Effect of reconditioning: left, 30 and 80 per cent relative humidity conditions (left and right halves, respectively): right, panels at 30 percent and reconditioned to 30 percent relative humidity (left and right halves, respectively); top, lumber core; center, 5-ply plywood core; and bottom, standard test particle board core.

from flakes of varying thickness, whereas the board made from edge-grain flakes is made from flakes of almost identical thickness. (2) Flat-grain flakes from Douglas-fir are likely to be either all heartwood or all sapwood; therefore, there is a wider difference in density of the flakes in the flat-grain board than in the edge-grain board. Either one or both of these characteristics could overbalance the difference between tangential and radial shrinkage for the species.

Effect of Crossbands: Standard Douglas-fir flake particle boards were prepared in the usual manner (including the sanding) and were then used to make test panels with five different crossbands. These were compared to a particle board with no crossband under the decorative laminate. The show-through patterns produced by these six test panels are shown in Figure 17. Again, the left-hand half of each panel was exposed to 30 percent and the right-hand half to 80 percent relative humidity for 2 months before the photographs were taken. The use of 1/16-inch yellow-poplar, red gum, and aspen, and 1¼-inch Douglas-fir veneer crossbands appeared to produce a slight improvement in the show-through pattern as compared to the particle board with no crossband. The use of a ⅛-inch-thick hardboard crossband, however, produced an improvement in the surface at the 30 percent condition and a marked improvement at the 80 percent condition. It is possible that an exposure longer than 2 months is necessary to bring the board with the ⅛-inch hardboard crossbands to equilibrium because of the increased thickness, but, inasmuch as the half exposed to 30 percent showed considerable improvement over the other crossbands at 30 percent relative humidity, it is reasonable to expect a permanent improvement from the ⅛-inch thick hardboard crossbands.

Effect of Reconditioning: To evaluate the effect of reconditioning to the original 30 percent condition on show-through, typical panels with crossbanded yellow-poplar lumber, plywood, and particle board cores were reconditioned for 2 months at 30 percent relative humidity. These three panels are shown, before and after reconditioning, in Figure 18. The long, wave-type imperfection, typical of lumber core, showed clearly in the 80 percent condition and was almost completely eliminated by reconditioning to 30 percent. Likewise, the typical crossed wave pattern of a plywood core at 80 percent relative humidity was considerably reduced by reconditioning at 30 percent. The typical mottled pattern of a particle board core at 80 percent was reduced by reconditioning to 30 percent relative humidity, but was still noticeably poorer than the left half of the board, which was continuously at 30 percent. The standard particle board in this panel was assembled in condition 1 (no preconditioning of the core).

Although the four conditioning variables of the particle board cores before they were laminated had no noticeable effect on the show-through pattern after conditioning one-half of the panel to 30 percent relative hu-

Table 1.—EFFECT OF ORIGINAL PRECONDITIONING ON SHOW-THROUGH OF RECONDITIONED PANELS

Conditioning before laminating	Core variables										
	25 lbs. per cu. ft.	35 lbs. per cu. ft.	Standard board[2]	45 lbs. per cu. ft.	20 percent moisture content face	16 percent moisture content	4 percent resin content	Shavings	Slivers	0.027 inch flakes	Total score
None	4	3	4	3	4	4	4	4	4	4	38
2 weeks 30% R.H.	3	4	2	2	3	3	3	2	3	3	28
2 weeks 80% R.H.+ 2 weeks 30% R.H.	1	1	1	1	1	1	1	1	1	1	10
Moisture on surface	2	2	3	4	2	2	2	3	2	2	24

[1] A rating of 1 is best, and 4 indicates the poorest surface.
[2] 40 pounds per cubic foot; 12 percent moisture content; 8 percent resin content; 0.015-inch-thick, 1-inch-long, random-width flakes.

midity and the other half to 80 percent, reconditioning of the right half again at 30 percent relative humidity revealed differences associated with the original preconditioning of the core. Photographs of 10 reconditioned groups of panels were studied, and in each group of 4, ratings of 1 to 4 were assigned in accordance with the perfection of the surface (a rating of 1 being best and 4 being least regular). The results of this inspection are shown in Table 1.

In all cases the panels made from cores that were conditioned first for 2 weeks at 80 percent relative humidity followed by 2 weeks at 30 percent relative humidity, then sanded and overlaid were judged to be best. On the basis of the total score, the cores that were treated with the required moisture on each surface to produce the proper moisture content for 30 percent relative humidity conditions were second, followed closely by the cores that were conditioned at 30 percent relative humidity for 2 weeks. The panels made from unconditioned cores produced the poorest pattern when reconditioned.

Conclusions

The evaluation technique used in this study of show-through of variables in particle board cores was found to be sufficiently sensitive for the purpose, and capable of giving reproducible results. Furthermore, the versatility of the technique makes it applicable for use on a wide variety of panel constructions with reasonably high-gloss surfaces of any color.

Application of the technique to evaluation of characteristics in particle board fabrication (observable through a high-gloss black decorative face) revealed that many of the variables thought to be important had little effect, but some, such as the use of fines on the surface, minimum of sanding, and sanding by a special technique, had a marked effect in improving the quality of the surface. Other variables such as thick flakes and slivers reduced the quality of the surface.

The use of typical veneer crossbands had little effect on the show-through pattern produced by the standard Douglas-fir flake particle board core; a 1/8-inch-thick hardboard crossband, however, produced a definite improvement.

There is no relation between quality of surface and average thickness increase of particle board cores due to an increase in equilibrium moisture content.

Edge-grain Douglas-fir flakes produced a more uniform surface at both 30 and 80 percent relative humidity conditions than did flat-grain Douglas-fir flakes.

Reconditioning of panels to the original 30 percent relative humidity condition after being exposed to 80 percent relative humidity for 2 months produced marked improvement in the surface. These surfaces were in general somewhat lower in quality, however, than the half of the panel that had been exposed continuously to 30 percent relative humidity.

Four different core conditioning treatments before sanding and application of the decorative laminate caused little or no difference in the show-through pattern, either at 30 percent relative humidity or 80 percent relative humidity condition. Upon reconditioning the half that had been conditioned at 80 percent, the original core conditioning treatment consisting of 2 weeks at 80 percent relative humidity followed by 2 weeks at 30 percent relative humidity was definitely better than the other three core treatments.

During the course of the study, many variables, as yet not investigated, were proposed for further work. A list of these might include:

1. Fabrication of boards at 40 percent relative humidity followed by exposure of panels to 15 and 80 percent relative humidity (typical of use conditions in northern states).

2. Laminating adhesive variables, such as type, temperature at cure, spread, pressure, and so forth.

3. Mixture of high- and low-density particles.

4. Aging at constant relative humidity.

5. Reversed cycling of moisture content.

6. Press cycles.

WHAT THIS RESEARCH MEANS

Although it is rapidly becoming competitive in cost with other materials, particle board has not fully succeeded in markets for which it was primarily designed. One factor that has retarded its application for such uses as core stock for fine furniture has been its characteristic show-through pattern, which differs from that of lumber or plywood.

As a result of the work reported here, a technique is available that provides a means of examining, evaluating and recording the show-through pattern (which is often called telegraphing) of panels made with particle board cores. Information obtained will point the way for commercial modifications and improvements of particle board.

Although the technique was devised as a working tool to evaluate show-through characteristics of particle board, it can be used equally well on any furniture panel, regardless of color or pattern of the finished surface or of the type of core. This means that its potential applications go way beyond the original concept. By making the apparatus portable, for example, it can be used as a valuable evaluation tool on actual furniture, perhaps for in-plant inspection, or as a method of evaluating the effect of certain service conditions on furniture. Simple modifications of the techniques could further amplify its uses to include the evaluation of the show-through characteristics of underlayment panels made of materials other than wood.

If you would like to duplicate this experiment in your laboratory or plant, or if you would like to modify the comparator for a specific purpose, the U.S. Forest Products Laboratory has available a technical note that describes the show-through comparator, sets forth the details of its manufacture, and tells how to read and interpret the grid pattern. The note includes an excellent preview of the set-up and a copy of the master grid used by the FPL. By photographing the grid replica with a 35 mm camera equipped with a 50 mm lens and a 3X portrait attachment, slides can be produced that are suitable for use with the comparator.

For copies of the technical note, write to: **The Editor, Forest Products Journal, 417 N. Walnut St., Madison 5, Wisc.**

INTEGRATED UTILIZATION VIA . . .

Tree-Length Pulpwood Logging

LOADING Tree-length pulpwood at St. Regis Paper Company's Suwanne Forest in Southern Georgia.

WEIGHT-SCALING tree-length logs at St. Regis Paper Company's chip mill in Fargo, Georgia.

T. N. BAKER
St. Regis Paper Co., Jacksonville, Fla.

THE KRAFT PULP INDUSTRY came to the south about 1910, at a time when the wood supply and the labor supply were both plentiful. Wood was originally delivered to the pulp mills on every conceivable conveyance at the miraculously low cost of $4.00 per cord. The industry has grown rapidly and wood is now consumed at a rate in excess of 20,000,000 cords annually. Forest labor, once plentiful, is now scarce, and competition for it is much keener. Supplies come mainly from tree farms, where it is grown as a crop specifically for pulp use. These changes in labor forces and availability of wood have made it obvious that methods and equipment used in harvesting pulpwood must be improved, if the demand is to be met at a reasonable price.

The Author: T. N. Baker, a University of Florida Graduate, has been manager of the Chip Engineering and Supply Department at St. Regis since 1955. The department furnishes 240,000 cords of wood chips a year to the St. Regis mills.

The need for a better system of pulpwood logging is growing daily. This demonstration of tree-length harvesting of all products shows that it reduces costs, recovers maximum volume from each tree, reduces labor problems, and results in improved revenues from the forest.

The following are some of the important developments in pulpwood harvesting: The development of the mechanized pulpwood yard where the 5 foot, 3-inch pulpwood bolts are transferred to railroad cars by machine instead of by hand; the pulpwood pallet system that affords a pre-packaged load and reduces the effort necessary for loading in the woods; the invention and marketing of various mechanical devices for woods-loading of the bolts on trucks; the development of a harvesting combine that completely mechanizes felling, limbing, bucking, and handling of the pulpwood bolts; multiple-length logging of pulpwood; and most recently, tree-length pulpwood logging. This latest step, tree-length pulpwood logging, its objectives, methods, equipment, efficiencies, and the opportunities for better and more complete utilization through integration with logging of other forest products is the subject of this paper.

The St. Regis Paper Company began tree-length pulpwood logging integrated with the logging of saw timber and poles at Fargo, Georgia, in January of 1958. Buckeye Cellulose at Foley, Florida, quickly adopted the system. The success of these two operations has stimulated interest, and plans are being made for similar operations by Brunswick Pulp & Paper Company, Hudson Pulp and Paper Company, Rayonier, Inc., and Union Bag-Camp Paper Corp.

The objectives of tree-length pulpwood logging are to reduce cost, improve the dependability of wood flow to the mill, afford maximum timber

[1] Presented Session XIII, Logging, FPRS 14th Annual Meeting, June 8, 1960 in Montreal, Canada.

CUT-OFF SAW used to cut sawlogs and poles or oversized portions of pulp logs; operator also sorts products and controls the chipper.

CHIP LOADING is done on system of belt and flight conveyors. The system is capable of loading 30 freight cars in 16 hours.

utilization, and alleviate the growing shortage of forest labor.

Fargo, Georgia is the site of St. Regis Paper Company's forest management headquarters for its 230,000 acre "Suwannee Forest" and of its Fargo Chip Mill. The forest is a tract managed under a long-term cutting contract and lying west of the Okefenokee Swamp in the South East corner of Georgia. The ground is quite low, wet, and flat with variations in elevation from 3 to 5 feet in any given area, and a general rise of about 1 foot to the mile in a north-westerly direction. The average annual rainfall is about 60 inches. Timber species are slash and longleaf pine. The growing and management of this timber is carried out by St. Regis Paper Company's foresters, but the logging is entirely by a contractor through several subcontractors.

Marked timber is felled, skidded, loaded, and trucked to the chip mill in tree-lengths. Trees are selected without regard for end use. Marking usually constitutes a thinning by the removal of the larger trees, but in some cases provides only for a seed tree stand to be left. The average volume removal is approximately 4½ cords per acre, with a residual stand of between 5 and 10 cords per acre left on the selective cut sites. Felling is done with a one man, blade-type chain saw. Single- and double-bitted axes are used for limbing. Skidding is all done by tractor without a sulky or an arch. The tractors used are all track type with track plates twenty inches wide. They are in the 50 to 60 draw-bar horse power class and are equipped with a logging winch. Logs are choked for ground skidding by ½-inch or ⅝-inch wire rope chokers with an eye splice at each end. These chokers are not preset. They remain fixed to the tractor draw bar and are attached to each log for skidding by means of a "C" link. Each tractor trails three or four chokers and usually skids one or two in the winch line. Some skids are pulled top first and some butt first. Logs are loaded from the landing by a front-end loader, also on track. Log loading keeps pace with the skidding operation; thus, little volume of timber is ramped ahead of loading. This practice creates some lost time in loading and some in skidding, but it has been necessary because of the very soft soil which might, at any minute, require the abandonment of a landing. The logs are loaded on a frame-type tandem log trailer with dropped-center section, fifth wheel, two-log bolsters, collapsible standards, and a swinging landing gear designed for maximum floatation. The most popular tire on this unit is a 17.00 x 20, 24-ply nylon aircraft tire that exhibits excellent floatation and good life. Each trailer load normally contains about 10 cords or 58,000 pounds net load. These trailers are moved through woods' trails to a graded road or fire break by an especially designed truck tractor, which is also equipped with 17.00 x 20, 24-ply nylon aircraft tires, except that these are capped with a mud-grip tread. The unit has a sliding fifth wheel for raising the goose neck of the trailer above the tires and for distributing a portion of the load to the front axle. All four wheels are powered, and the short-coupled, off-highway truck tractor is built for the rugged duty of moving the loaded trailers through the woods. Roads or graded fire breaks, (which the loggers use as roads) are built and maintained on 2-mile intervals; hence, the off-highway movement of a trailer seldom exceeds 1 mile. Upon reaching the grade, the woods truck drops the loaded trailer and picks up another empty for loading. The highway truck returning from the chip mill drops its empty trailer and picks up a loaded one. Thus, the woods operation and highway trucking operation are separated with the prepackaged load allowing each to be more efficient.

Normally each subcontractor owns and manages only one logging unit, and its crew is made up as follows:

1 saw man
1 limber
1 choker setter
2 skidding-tractor operators
1 loader operator
1 deckman or woods truck driver
1 highway truck driver
1 foreman, who normally is the subcontractor

Total 9 Men.

This typical unit with nine men usually attains a production rate of 50 to 60 cords per day or about 6 cords per man day under the tree-length system, while the average production rate per man day is 1¾ cords when 5-foot 3-inch pulpwood is logged. Hence two men in tree-length logging are equal in production to seven men in bolt-length logging.

Tree-length pulpwood logging is also less subject to stoppages in bad weather because the equipment used is more adaptable to wet ground than is conventional equipment. This means steadier employment and higher production rates. Although investment and other costs are higher, tree-length

ılpwood logging affords the con-
ıctor a better profit and delivers the
ood at a lower cost. This enables him
get and hold good loggers.

Tree-length pulpwood offers the
st opportunity for integrated utiliza-
n of southern pine timber. A system
· sorting the various products is all
ıt is required to integrate the log-
ıg of poles, saw logs, and pulpwood
tree-length. Selection and trimming
. be performed in the woods or at
: chip mill. The objectives of such
.. integration are to lower the cost of
: gging each of the commodities by
· reasing the volume of removals
ıom each acre and by eliminating the
ı tracing of steps common to separate
erations for poles, sawlogs, and
pulpwood. Financial returns from the
forest are improved because each part
of each tree can be allocated to its
highest economic use, regardless of its
remoteness from other trees of similar
grade, and because the entire stem of
saw log and pole trees is used.

The chip mill at Fargo receives the truck loads of tree-length logs, weight-scales them, unloads the logs, debarks them, passes them under a cut-off saw to cut the poles, sawlogs, and oversize portions of pulp logs. Poles and sawlogs can be kicked out for sale, and the balance is chipped.

The truck scale at Fargo has a 100,000-pound capacity with a 10- by 50-foot platform, and it is equipped with an automatic printer. Upon arrival, the weight-scale ticket is marked with the contractor's name and truck number, source by land ownership from which the wood comes, the county, the species, the time and date of arrival, and the gross weight of the truck load. After the truck is unloaded, the ticket is again stamped by the printer to indicate the tare weight of the truck. The net weight and cordage is computed and the time out is marked on the ticket. The log-scale tickets are arranged in sets consisting of one original and four copies with a disposable carbon between each sheet. The original of this ticket is forwarded to accounting for payment of stumpage to the land owner and for payment to the logging contractor. The first copy is kept for the mill's record. The second copy is forwarded to the land management department for their record of removals. The third copy is forwarded to the primary logging contractor, and the fourth and final copy is given to the truck driver as a receipt for his load. After loads are weighed in, they are moved to either of two log decks where power equipment slides the logs from the bolsters of the truck on to a 220-foot long steel ramp. This movement is effected by a pair of sliding arms moved by cables and drums from the opposite end of the ramp. Logs are moved forward in bunches of 1 to 2 truck loads and stored on the decks. The same sliding arm that unloads the truck is used to break down the piles of logs at the other end of the deck and feed them into a chain conveyor, one at a time. All work at the unloading end of the ramp is done by the truck driver, while the movement of the arms is controlled by an operator in an elevated control room at the opposite end of the ramp. This operator is assisted by a deck man to maintain a continuous stream of logs down the first conveyor to the ring-type, 30-inch debarker, operating at a speed of 130 linear feet per minute. The debarker operator controls the movement of the infeed log conveyor as well as the debarking operation. The next operator at the cut-off saw is in position to trim poles and sawlogs, sorting them with the appropriate air operated kicker and diverting oversized portions of a pulp log to the breakdown rig. This breakdown rig consists of a short, live-storage deck for the accumulation of oversized logs, small carriage, hydraulic stop and loader and log turner, a circular saw, and a transfer for the slabs and cants back to the chipper where they join other pulp grade logs passing down the sorting conveyor and directly into the chipper feed. The chipper is an 84-inch, 8-knife chipper with a horizontal feed and gravity discharge. It is powered by a directly connected 900 hp. total enclosed fan cooled motor, turning 450 RPM. Chips are transported to the car and loaded by a series of three conveyors. The first is a flight conveyor which discharges them on to a 36-inch belt. The belt elevates the chips and discharges them on to a second flight conveyor that spans three tracks and loads a waiting car on either of these three tracks. The last operator in the mill controls this loading. The mill at Fargo is operating two 8 hour shifts per day at better than 25 cords per hour. Each shift employs five operators, a foreman, and a millwright. The mill superintendent and the log scaler complete this team that produces approximately 80,000 cords of wood chips a year.

Logging pulpwood in tree-lengths and processing it through an operation similar to the one described results in a 5-percent increase in pulpwood volume recovery, utilization as compared with conventional logging of pulpwood bolts. This is the result of a reduction of the minimum top diameter from 4 inches to 2 inches and the elimination of saw-kerf. Logging pulpwood bolts often fails, however, to recover all of the available timber. Occasionally an oversize bolt, too heavy for hand loading, will be left or a down tree will be passed if the truck is unable to drive close enough for loading. In actual practice, therefore, the improved yield for tree-length logging often exceeds the 5 percent cited above. In addition the tops and low-grade portions of saw log and pole trees are recovered for pulp. The result again is more complete utilization of available fiber. Better as well as more complete utilization of timber, is achieved by the integrated operation because each piece can be allocated to its highest economic use, sawlog and pole lengths can be cut accurately, and because concentration of the various grades in sufficient volumes to demand top market price is possible.

The importance of a system of pulpwood harvesting that is better than the shortwood operations known today, is growing day by day. The current program being proposed by the American Pulpwood Association for a research project to study pulpwood harvesting is evidence that this is a major problem in our industry. Of the many avenues open for improving pulpwood harvesting, integrated tree-length logging of all forest products appears to be the most promising. It reduces cost, improves reliability of wood supply, recovers the maximum volume of wood fiber from each tree harvested, makes maximum use of available labor, and improves the revenue from the forest land.

Observe National Forest Products Week

October 16–22, 1960

A PANEL DISCUSSION ON . . .

Plywood Automation[1]

Panel Moderator

DR. BEN S. BRYANT
College of Forestry, University of Washington, Seattle

Representatives of two adhesives manufacturers, an industrial engineering firm, and a plywood machinery manufacturer discuss technical developments and economic facts of this timely subject.

IN RECENT YEARS THERE HAS BEEN increasing motivation for plywood manufacturers to make operations more efficient. Higher costs of labor, raw materials and equipment as well as the impact of imported plywood have undoubtedly provided a stimulus for more efficient production. But the West Coast softwood plywood industry is also cursed with great fluctuations in price for its product. In periods of famine, such as currently exist, only the most efficient plants can produce at a profit, even if the factor of log costs is most favorable.

When one looks at the softwood plywood industry as a whole, the signs are encouraging. Devices have been installed to improve the economic efficiency of charging the lathe, peeling, offbearing, dryer feeding, detecting moisture, jointing, edge gluing, patching, loading and unloading the press, panel trimming, sander feeding and panel patching.

Few, if any plants even the newest, take advantage of all of this equipment. If it were employed, the plant could scarcely be called fully automated. It would be apparent that the separate operations had been rendered more efficient in terms of labor involved and production per machine. However, the material flow through the plant would still be by batches and the absence of interconnecting conveyors would be conspicuous.

Those who are familiar with steps involved in plywood manufacture will have noted the absence of reference to the glue spreading and layup process in the above list. Aside from one to two attempts at automatic core laying, this essential step in the process remains one of the most wasteful of manpower and expensive in terms of unit cost.

In what rational basis are decisions reached regarding whether or not more efficient equipment should be installed in a plant? The answer to this question lies in accounting philosophy as well as an understanding of costs.

Where can we look for new approaches to the automation possibilities in plywood manufacture? Machinery manufacturers who have been providing equipment for the particle board and hardboard industry are in a position to tell us how automation techniques used in those industries can be adapted and applied to plywood manufacture.

Here are reports by representatives of two adhesive manufacturers, an industrial engineering firm and a machinery manufacturer. They present an authoritative resume of the latest technical developments in gluing and layup operations, the economic engineering of unit automation, and of the developments in machinery and techniques that will eventually bring the dream of making plywood automatically to reality.

Whenever progress occurs in any industry, there are leaders behind that progress who have had a vision, who have pressed toward their goals, sometimes in spite of great difficulties, and who have been able to work out their ideas by teaming up with others who shared their dream and were in a position to help them develop it. The authors of the reports you will read here are such men. The future of automation in the industry depends upon the willingness of management to give them, and others like them, the opportunity of selling their ideas and of demonstrating the effectiveness of their thinking.

Automation with Dry-Film Adhesives[1]

R. K. STENSRUD
Reichhold Chemicals, Inc.
Seattle, Washington

THIS PROPOSAL IS FOR A ONE-grade plywood mill. There have long been grading rules established for softwood plywood which limited the number of patched defects for certain grade faces, backs, etc. The allowable number of patches for an A face has increased over the years to where 18 patches are now allowed per 4 x 8 "A" face. An N-grade is now available as well. This so-called "Natural" grade is intended for use in the limited number of applications wherein the Douglas-fir will be finished naturally with, say, varnish, shellac, resin sealer, lacquer, etc. There will undoubtedly always be a certain need for some plywood of this grade. The majority of plywood used, however, probably falls in a class where the plywood is used for sheathing, underlayment for resilient flooring, underlayment for decorative plastics, countertops, the structural part of cabinets, floorboards for trucks and automobiles, signboards, packing cases, structural portions of furniture, etc. In most of these applications, the plywood is either left unfinished or is painted with an opaque paint. Through the advent of plastic-fiber combination overlays and materials of this sort, most any kind of repaired face can be successfully overlaid and successfully painted.

The Author: Russell K. Stensrud, a graduate of the University of Washington, is Manager of Technical Service for Reichhold's Pacific Northwest Division.

[1] Part of a panel discussion presented at session XII, Glues and Gluing and Veneers and Plywood, FPRS 14th Annual Meeting, June 1960 in Montreal, Canada, approved for publication July 1, 1960.

In most applications where the ultimate consumer wishes to have a decorative, natural wood panel, he will specify one of the special types of softwood plywood surfaces, such as fire brushed or etched plywood of some type or, which is more likely, he will specify a hardwood-overlaid plywood or one of the more decorative softwood panels such as knotty pine, knotty cedar, or vertical grain fir.

This proposal, then, is to make a panel which we can refer to as a utility panel or for certain uses, a core panel. This certainly does not limit its applications but rather aptly describes it. This panel could then be used as is for underlayment, sheathing, structural uses as mentioned above; or overlaid with a plastic overlay for use as concrete form.

Many of the principles that will be explored in this section of the presentation are not limited to use in a one-grade mill but are equally applicable to the ordinary many-grade mill. Many of the basic principles could also be applied to hardwood—overlaid softwood plywood manufacture.

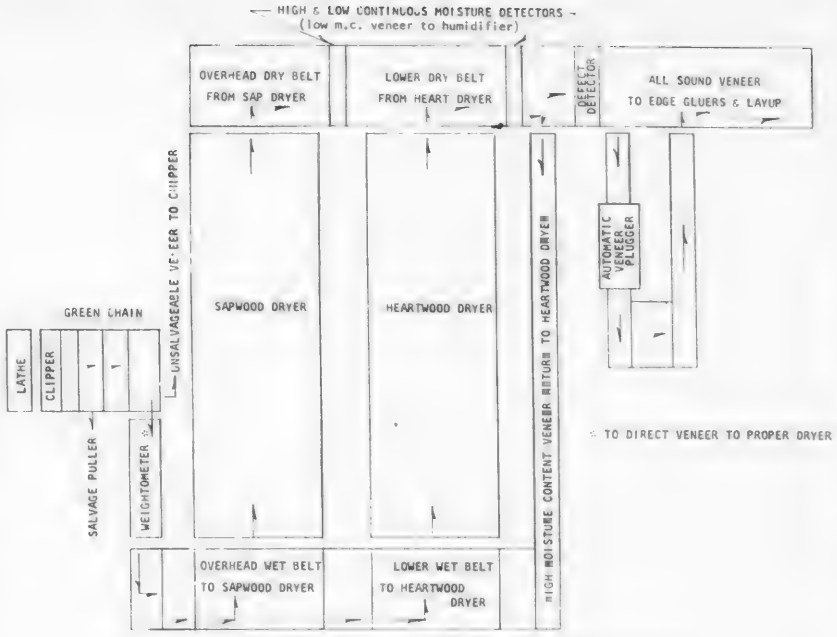

HIGH & LOW CONTINUOUS MOISTURE DETECTORS
(low m.c. veneer to humidifier)
OVERHEAD DRY BELT FROM SAP DRYER
LOWER DRY BELT FROM HEART DRYER
DEFECT DETECTOR
ALL SOUND VENEER TO EDGE GLUERS & LAYUP
UNSALVAGEABLE VENEER TO CHIPPER
AUTOMATIC VENEER PLUGGER
GREEN CHAIN
LATHE
CLIPPER
SAPWOOD DRYER
HEARTWOOD DRYER
HIGH MOISTURE CONTENT VENEER RETURN TO HEARTWOOD DRYER
SALVAGE PULLER
WEIGHTOMETER
TO DIRECT VENEER TO PROPER DRYER
OVERHEAD WET BELT TO SAPWOOD DRYER
LOWER WET BELT TO HEARTWOOD DRYER

Fig.1.—Flow chart of conveyor system carrying veneer to dryers.

A hypothetical, one-grade plywood mill is described, and recommendations are given on log selection, standardized clipping and peeling, defect limitations, green-chain sorting, and layup practices with a dry-film adhesive system.

Log and Peeler Selection

The optimum log grade should be determined for the grade of plywood to be produced, and good sorting and selection of logs and marking and cutting of peeler blocks must be instituted. This is especially important in a well integrated forest products utilization operation. In an operation that might include a saw mill, one or more plywood mills, a composition board plant, and a pulp mill, just about any log that might be brought in out of the woods could be utilized to the best economic advantage commensurate with grade recovery and current market conditions for the various products. In the plywood mill described here, it would not be economical to indiscriminately mix no. 3 sawlogs with no. 1 peeler logs, when perhaps a no. 1 or no. 2 sawlog, for instance, is the optimum grade to peel in this certain operation.

Standardized Peel

Most western softwood plywood manufacturers peel three thicknesses for the majority of their plywood. These are 1/10, 1/8 and 3/16 inch. With combinations of these three thicknesses, almost any standard plywood thickness can be constructed. Data collected by the Douglas Fir Plywood Association and the Plywood Research Foundation of Tacoma, Washington indicate that there are as many as 12 nominal veneer thicknesses peeled at the present time. These are 1/16, 1/12, 1/10, 1/9, 1/8, 1/7, 5/32, 1/6, 7/16, 1/5, 7/32, and 1/4-inch. These thicknesses are peeled in about 12 different thicknesses for each nominal thickness. Therefore, there can conceivably be as many as 150 "standard" veneer thicknesses used. The common constructions in the western softwood plywood industry; for example the 5/16, 7/16, 9/16, 11/16, and 13/16 inch thickness which comprise most of the plywood made in the industry, and which is later sanded to 1/4, 3/8, 1/2, 5/8, 3/4 inch, respectively, could be made with a single veneer thickness. This would be practical, with the two glue systems discussed here. For example, a mill making sanded constructions, such as those mentioned above, could use, for instance, a 1/9-inch peel. This is theoretically 0.1111 inches, but it is commonly peeled in the industry to an average of 0.112 inches and will range from 0.111 to 0.114. This single veneer thickness could be used to produce the 5 standard rough thicknesses shown in Table 1. Some unorthodox numbers of plies appear in the table. For instance, 7/16 inch is made with 4 plies of 1/9. In using standard glue spreader layups, such a construction would be impossible. Using either of the glue systems described here; however, the core in the case of conventional 3-ply panels or the centers in the case of conventional 5-ply panels can be doubled up and laminated parallel to the grain to produce a thicker panel with somewhat thinner-than-usual veneer thicknesses. Table 2 shows a similar set of constructions for sheathing plywood that could be all made with 1/10-inch veneer.

Defect Limitation

The Plywood Research Foundation of Tacoma, Washington and others have done considerable work in automatic detection and rejection of "thick and thin" veneers. This is usually done at the green veneer stage, to prevent wasting money by drying veneers that are not usable for making quality plywood. Besides the waste in drying this ultimately unusable veneer, there is the additional waste in veneer patching, and waste of glue. Additionally, if defective veneer is made up into plywood, the layup, pressing, sawing, patching, sanding, and inspection all increase the cost of this piece of veneer. If the plywood then delaminates and is rejected, not only is the thick or thin veneer wasted, but all the rest of the veneers in the panel and the glue are also wasted. We look for excellently engineered, well-instrumented systems for detecting and reject rough or thick and thin veneers be installed and operating within the next few months.

Standardized Clipping

We propose to set up in this hypothetical mill an automatic clipper that would clip the veneer to one of two possible widths. This clipping would be done without benefit of a human operator. The major advantages to this type of clipping would be (1) saving in manpower in the clipping and sorting of the green veneer, (2) there should be less downgrade of veneers in the dryer due principally to shrinkage of the traditional wide sheets in a roller dryer. This downgrade in conventional mills is ordinarily handled by end taping before layup or shim patching the panels either just after pressing or just after their first sanding. (3) Handling and stacking of veneers in one width would simplify storage and transportation problems.

Two such "standard" widths might be 17 and 27 inches. A mill making all 27-inches wide stock would edge glue or otherwise join two 27's to make a 50-inch face, back, or center. Four of these 27's cut in half lengthwise could be used for "tailor-made" core for a conventional spreader operation, or they could be edge glued or otherwise joined for one-piece cores.

Another "standard" width might be 17-inches. Three pieces 17-inches wide would form 50-inch faces, backs, and centers, and six widths of 17-inch core would constitute a conventional 100-inch plywood panel.

Green Chain Sorting and Drying

This proposition would indicate that no sorting for grades would be done at the green chain. No sorting for heart or sap would be done on the green chain. Veneer that was not a whole standard width and length would be surveyed for possible cutting back for use as core material or, in the extreme case, it could be clipped to recover clear material along one edge. (See Figure 1 to follow this flow.) The economics have not been studied, but it would be entirely within reason that a piece of veneer that would have to be subsequently handled several times in order to make a sound piece out of it would be better utilized if it were made into pulp chips. Whole width and length pieces leaving the green chain would then travel down a conveyor, installed in which would be some sort of weighing device for weighing the individual pieces of veneer as they pass a certain point. This weighing would indicate the moisture content of an individual piece of veneer. One must bear in mind that density variations in the veneer are possibly due to such things as difference in annual ring count, percentage of summerwood, site, etc. Within one run of logs from a certain area, however, this weighing device could be quite accurate for determining the drying time necessary for that particular piece of veneer. This weighing device could actuate an automatic transfer system which could carry the high moisture content pieces down one conveyor and the low moisture content pieces down another conveyor. These two conveyors could lead to either a "split-feed" multi-deck dryer or to two separate veneer dryers. In the Douglas-fir industry, for instance, it has been found that the veneer that finally gets to the point of drying is about 1/3 sapwood and 2/3 heartwood. It has been established that sapwood dries at about half the rate of heartwood; therefore, half of the physical space when using two dryers would be devoted to heartwood, the other half to sapwood. Likewise, a split-feed dryer would be split evenly so that the 1/3 sap being dried at approximately ½ the rate of the heartwood would occupy as much space as the 2/3 of the veneers which are heartwood.

All veneers, when emerging from the dryer would pass under a continuous moisture detector and marker. This machine could be set so that it would sense veneer that is too high in MC and actuate a return mechanism to feed any veneer so marked, to the in-feed side of the heart dryer or heart section of the split-feed dryer. Assume that the veneer has been dried without significant down grade, and veneers which are too high in MC have been returned to the green end of the dryers. We now have veneer traveling along a conveyor belt which is all of "optimum" MC, and is all the same width and length.

At this point, a relatively simple scanning system could be used to determine which sheets of veneer would need patching in order to make an all-solid-veneer panel. This device could be a piece of electronic equipment that would scan the sheet. Any piece of veneer that would pass light from one side to the other would sense a jump roll or jump belt system which would divert that piece of veneer momentarily for patching. This patching could be done in a conventional mill with the conventional single-action patchers. The veneer could travel off the dry belt past the patching station and return to the dry belt on a "merry-go-round" as may be found in almost any sawmill. In other words, the patched veneer will rejoin the train of sound veneer. The number of such patching stations would have to be learned by experience, or a continuous patcher, which will be available in the near future could be used.

At this point, all the veneers would be solid. If it is economically feasible to sort out high grade veneers at this point for use in another layup plant or for sale on the open market, then this is the point at which it should be segregated.

Also at this point, those veneers which would make better face stock, depending upon the particular grade set up of the mill, could be diverted to a face edge gluer. Those veneers to be used for cores could be diverted to a core edge gluer prior to whi (or after, which is common in so mills today), the veneer would ha been cut to core length. Cente would be edge glued, if such is t panel layup process, and backs woul of course, also be edge glued. Sin panel patching is an expensive proces it behooves us to do an exceptional good job of face and back edge gluin almost without regard to the end us

Table 1.—PLYWOOD CONSTRUCTIONS MADE UP OF SINGLE THICKNESSES OF 1/9-INCH SANDED VENEER CONSTRUCTIONS

Rough Thickness	Number of Plies	Veneer Thickness	Total Thickness	Nominal Rough Thickness	Nominal Sanded Thickness	Sanding and Compression Allowance
5/16	3-plies	0.112*	0.336	0.313	0.250 ± 0.0156**	0.086
7/16	4-plies	.112	.448	.438	.375 ± .0156	.073
9/16	5-plies	.112	.560	.562	.500 ± .0156	.060
11/16	6-plies	.112	.672	.688	.625 ± .0156	.047
13/16	7-plies	.112	.784	.812	.750 ± .0156	.034 to .06***

*All decimal thicknesses in inches.
**Commercial Standards 45–55 (Douglas Fir Plywood) and CS–122–56 (Western Softwood Plywood) allow a ± 1/64 (0.0156) variation from nominal thickness for sanded plywood.

Table 2.—PLYWOOD CONSTRUCTIONS MADE WITH SINGLE VENEER THICKNESSES OF 1/10-INCH SHEATHING CONSTRUCTIONS

Rough Thickness	Number of Plies	Veneer Thickness	Total Thickness	Nominal Rough Thickness	Variation from Nominal Rough Thickness	Within Commercial Standards Allowance**
5/16	3-plies	0.105*	0.315	0.313	+0.002	Yes
3/8	4-plies	.105	.420	.375	+ .045	Yes
1/2	5-plies	.105	.525	.500	+ .025	Yes
5/8	6-plies	.105	.630	.625	+ .005	Yes
3/4	7-plies	.105	.735	.750	— .015	Yes

*All decimal thicknesses in inches.
**Commercial Standards 45–55 (Douglas Fir Plywood) and CS–122–56 (Western Softwood Plywood) allow a + 1/32" (0.0312) variation from nominal thickness for sheathing plywood.
***Compression would probably put the net thickness within limits.

. the final panel, aside from sheath- ; use. Therefore, most face and back s ck should be jointed before edge ing. Core could be "saw-jointed" l then edge glued, or taped into full s sheets of veneer for panel layup.

Layup

All previous considerations would b applicable to several different glue s ems, but from this point on a spe- c glue system and how it may be u d for making plywood in this hypo- th ical mill will be considered. This h othetical mill may be operated w n standard loading and pressing equipment, or we might automate the loading and pressing operation. The particular layup scheme presented here is just one of many. Several schemes have been used in the layup of plywood with film glue. These schemes varied from a simple two-man layup setup for 5-ply panels to a more complex system involving several men and a conveyor belt for making up the panels. In all these systems, the greatest lack seemed to be the one piece cores with the film applied to both sides. Another common nemesis of press loading personnel is the "slipperiness" of a panel made up using film glue. Because of lack of friction, the panel is difficult to load as a unit without fastening the veneer together. A completely dry panel will not "break" at the loading elevator as quickly and positively as a panel laid up with liquid glues, which are somewhat tacky. Most of these objections would be overcome by installing a system along the lines which are shown here, and combining it with the more sophisticated press charging and handling equipment.

The film glue made by Reichhold is a pure phenol-formaldehyde resin supported on a cellulosic carrier for ease in handling. The product weighs 12½ to 13 pounds per thousand square foot and contains approximately 8 pounds of phenol-formaldehyde resin solids on a volatile-free basis. This is equivalent to a 60-pound spread of a conventional liquid phenol-formaldehyde glue extended with a filler and water. The resin solids content of such a mix is approximately 25 percent. Therefore, the resin solids on a double glue line would be approximately 15 pounds. The resin solids of the film on the ume volatile-free basis would be approximately 16 pounds.

At the present time, this product is manufactured only in Seattle, Washington. It has been shipped around he world to users in Europe, Africa, Asia, Australia, South America and, of ourse, points all over the North American Continent. It is being used at the present time by several manufacturers in the Eastern Canadian hardwood plywood manufacturing region. The product is in every day use in the Los Angeles, California aircraft plywood industry as well as by several manufacturers on the West Coast for overlaying particle board and plywood "core panels" with hardwood veneers. One large flakeboard manufacturer makes hardwood-overlaid panels in a one-step process by laying a sheet of film glue and then a sheet of hardwood veneer over the felted mat before the panel is inserted in the board press.

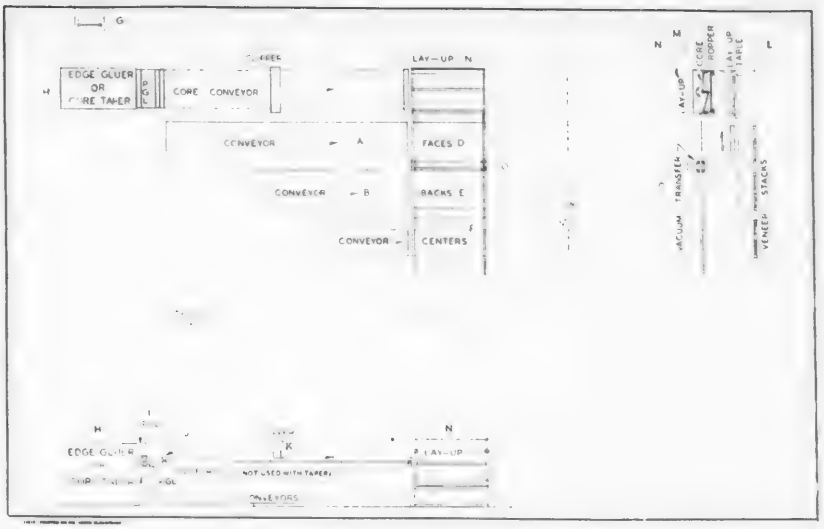


Fig. 2.—Conveyor system for plywood panel layup with dry-film adhesives.

The film is shipped in rolls approximately 4000 feet in length and either 38, 50, or 62 inches in width. The rolls are wound on a 6-inch (i.d.) fiber core.

In this layup scheme, faces, backs, and centers edge glued to standard 50 by 99 or 50 by 100 inch size are placed on loads on their respective conveyor—A, B, or C as shown in Figure 2. These move forward on gravity rolls and are braked automatically before they go into place on the automatically controlled scissors lift, D, E, and F. When any one of the stacks, D, E, or F, is depleted, the vacuum transfer mechanism G would stop functioning. The proper scissors lift would return to its bottom position, and the braking mechanism on the gravity roll conveyors would release the next load to the scissors lift.

As core is fed into this system, it advances into either an edge gluing or taping section and passes through a set of line rip-saws that square up the edges of the core before they enter the taper. This system is possible because of the constant width of the core. This "saw-jointing" should conserve a substantial amount of wood. In an ordinary edge gluing operation where conventional jointing is done (and incidentally, this jointing is probably necessary for face and back stock) from 4 to 8 percent of the veneer is wasted in jointer shavings. This saw-jointer setup should be able to trim to much closer tolerances with much less waste. The core would then advance into the core taper section where it would move transversely through the small crowder section which would apply a double gummed tape to top and bottom of the core at the extreme ends of the pieces of veneer. This tape would be applied to top and bottom of the veneer. The outside face of the tape (top of the top tape and bottom of the bottom tape) would not be moistened until after the tape had been firmly pressed onto the core stock moving through the taper. Just beyond the taper, the unmoistened side of this gummed tape would be moistened. Just "downstream" from this second moistener, a sheet of film glue would contact the veneer from a roll suspended above and below the 3-ply assembly and then go through squeeze rolls to finish the "tacking" operation, which would leave a continuous stream of jointed, edge-fastened core veneer with film on both sides.

In this particular lay-up this 3-ply core assembly would be clipped to panel length and would then travel on a conveyor to the layup section (L, M, N). This one-piece core would transfer into core-dropper (N). The core when it reached the extreme downstream end of the core-dropper would contact a limit switch which would be energized only when the vacuum transfer unit (O) was out of the "drop" position. This limit switch would then actuate a cylinder on toggle (M) which would drop the

3-ply core assembly onto the layup, guided into proper position by the slanted back board (I).

Vacuum transfer (O) would have first laid a face onto the layup table. The core would follow, while the vacuum transfer was going back after a center which would be laid onto the core assembly. While the transfer was returning for the back, another core assembly would be dropped by the core dropper. The vacuum transfer would then drop a back onto the assembly, and one panel would be complete. This panel would then transfer "end-o" on a conveyor to a "packaging section". Here, the panel could be held down momentarily while an automatic stapler would drive two or three staples on each edge of the panel (outboard of the path of the trim saws) which would hold this panel package together for simplified loading in the press. This package could then, if automation of layup was to end here, be simply made up into a package of 20, 25, or 30 panels for whatever number of openings exist in the press installed in this plant. These panels could then be loaded into a press charger and subsequently loaded into the press by the charger in the conventional manner of today, or hand-loaded directly into the press.

These same panels could travel from the "packaging section" along a conveyor and into an indexing, end-loading press charger. This press charger would then move forward to an end-loading hot press where the panels would be charged upon completion of pressing of the load previous, and the unloading of completed panels and loading of the new panels would be complete. To keep the operation moving smoothly, either two chargers would have to be employed for each press or an adequate storage conveyor with a "hurry-up" section in it would have to be provided for panel storage ahead of the loader while the loader is advancing to and charging the press. This is but one of possibly a thousand different setups which would be possible for laying up panels with film glue in an automatic or semi-automatic manner. This process would lend itself well to making the four-ply panel which was mentioned earlier by simply setting up the timing device on the vacuum transfer so that two core assemblies would be dropped between the time when the face was dropped on the table and the back finally laid. To manufacture a six-ply panel, the timer assembly on the vacuum transfer would be set to lay a face, a core, a center, a sheet of film glue off a stack of cut sheets, another center, and then proceed to lay another core assembly from the core taper, followed by a back.

Manufacturers of vacuum cup handling systems feel that this system is practical and could be set up at any time.

At the present time, very few post-layup operations are performed on plywood assemblies before they are charged into the press. Transport is required, and in some case the rough core overhang is trimmed off with a bandsaw. The automated layup systems described here eliminate the core trimming since the veneer is pretrimmed.

Traditionally, the layup area is very compact. The automated layup systems tend to be long, and it is possible that one layup machine will feed a battery of presses. We believe that plant layout should not be inhibited by requiring the layup area and press area to be very close. Underfloor or overhead conveying of small assembled panel packages for several hundred feet is practical.

New post-layup processes that are under consideration are prepressing and automatic stapling. Both operations are designed to provide a well consolidated package to permit fully automatic loading of press chargers

Economics of Automation in Plywood Manufacture[1]

C. A. HERSTROM
Industrial Engineering and Contracting Co., Portland, Oregon

For economic success, automation requires measurable side benefits, and an investigation of its potential must include careful review of other operations to see if any effect is of the best interest costwise.

THE PLYWOOD INDUSTRY, LIKE other industries, is interested in reducing costs, or in increasing income, and looks to "automation" as a means.

It may be helpful if we attempt a definition of "automation". The word implies that the action involved is self-motivating. In the practical sense that is not quite true. What is probably more true is that the application of "automation" requires a change in equipment, in methods, in instrumentation, and in practically all cases, some changes in "before and after" methods and procedures in order to apply the new method, or improve the old method.

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Such improvements may increase the utilization of existing capacity, raise the general level of production, increase volume or value recovery, improve quality, or any other improvement which shows an economic benefit. Reducing costs or increasing income is a "must".

A Typical Plant

To assess a potential application of automation, let us assume that a plant produces 6,500,000 feet of ⅜-inch plywood monthly. It has been in operation for a year, and when originally installed, site and all, it cost $3,100,000. The plant employs about 250 men in direct labor and 25 in indirect labor with a ⅜-inch footage per man hour of about 140 feet. It produces mostly sanded plywood, some sheathing and

[1] Part of a panel discussion presented at Session XII, Glues and Gluing and Veneers and Plywood, FPRS 14th Annual Meeting, June 1960, in Montreal, Canada; approved for publication July 1, 1960.

Table 1.—MONTHLY OPERATING COSTS AND MARGINS

	(1)	(2)	(3)	(4)	(5)	(6)
I duction level—3/8	6,500,000	6,500,000	6,500,000	6,500,000	7,000,000	7,000,000
I reciation base	10 Year	5 Year	10 Year	5 Year	10 Year	5 Year
I rement expenditure	None	None	$200,000	$200,000	$200,000	$200,000
L s to veneer	$ 27.60	$ 27.60	$ 27.60	$ 27.60	$ 27.60	$ 27.60
D ct labor						
reen end	5.61	5.61	5.61	5.61	5.21	5.21
ryers	3.65	3.65	3.65	3.65	3.39	3.39
neer processing	2.59	2.59	1.86	1.86	1.86	1.86
nel layup	3.57	3.57	3.57	3.57	3.32	3.32
achine finish	.90	.90	.90	.90	.84	.84
and finish	.98	.98	.98	.98	.91	.91
ad and ship	1.06	1.06	1.06	1.06	.98	.98
elief, utility, etc.	2.04	2.04	2.04	2.04	1.89	1.89
In ect labor and super- ion	2.40	2.40	2.40	2.40	2.23	2.23
G	5.00	5.00	5.00	5.00	5.00	5.00
S lies	2.60	2.60	2.60	2.60	2.60	2.60
P r	1.80	1.80	1.80	1.80	1.80	1.80
A inistration	2.15	2.15	2.15	2.15	2.00	2.00
Manufacturing cost	$ 61.95	$ 61.95	$ 61.22	$ 61.22	$ 59.63	$ 59.63
Depreciation	3.97	7.94	4.23	8.46	4.23	8.46
Total cost	$ 65.92	$ 69.89	$ 65.45	$ 69.68	$ 63.86	$ 68.09
Selling price	76.50	76.50	76.50	76.50	76.50	76.50
Net margin	$ 10.58	$ 6.61	$ 11.05	$ 6.82	$ 12.64	$ 8.41
Monthly gross profit	$ 68,800	$ 43,000	$ 71,800	$ 44,300	$ 88,500	$ 58,800
Annual gross profit	825,600	516,000	861,600	531,600	1,062,000	705,600
Less 50% taxes	412,800	258,000	430,800	265,800	531,000	352,800
Investment	$3,100,000	$3,100,000	$3,300,000	$3,300,000	$3,300,000	$3,300,000
% Annual return	13.3	8.3	13.0	8.1	16.1	10.7

industrials, as well as chips and residual cores for sale. The monthly operating statement appeared to be:

MONTHLY OPERATING COST (1000 SQUARE FEET, 3/8-INCH BASIS)

Logs into veneer		$27.60
Direct labor		
Green end	$5.61	
Dryers	3.65	
Veneer processing	2.59	
Panel layup	3.57	
Machine finish	.90	
Hand finish	.98	
Load and ship	1.06	
Relief, etc.	2.04	20.40
Indirect labor and supervision		2.40
Glue		5.00
Supplies		2.60
Power		1.80
Administration		2.15
Depreciation (10 years, straight line)		3.97
Manufacturing cost		$65.92

The Situation

The plant had been operating under full production conditions and the situation was something like this. It had been determined that "veneer processing" with various single unit production machines was the bottleneck. Space was limited to install additional machines, and it was not practical to go to three shifts. There was additional capacity in the other cost centers which could be realized, to about 8 to 10 percent, providing that the veneer processing problem could be solved.

A large machinery company had developed and proved, on a pilot basis, a new large packaged installation which would replace the individual machines and the out-of-pocket costs, after salvage of existing equipment. The installation of the new process was $200,000. The machine would eliminate 9 men directly, each costing about $530 per month in total wages, fringe benefits, and employee programs.

There was the potential of raising the overall level of production throughout the plant, provided that the new process could relieve the "bottleneck", and it appeared that the changes necessary to do this could be made, with little difficulty; however, they could not be made unless the new processing operations were proved.

There was a further aspect to consider. The plant might be faced with the problem of being shut down after 5 years, instead of the 10-year period as was planned originally.

Considerations

Management set up the following conditions to assess the problem:

(1) A $76.50 selling price, a 10-year depreciation base, and 50 percent taxes.

(2) A $76.50 selling price, a 5-year depreciation base, 50 percent taxes.

(3) Spend the $200,000, eliminate 9 men, 10-year depreciation base, 50 percent taxes, same selling price.

(4) The same as (3) but with a 5-year depreciation base.

(5) Spend the $200,000, eliminate 9 men, raise the production level to 7,000,000 feet on a 3/8-inch basis, same selling price, and taxes, with a 10-year depreciation base.

(6) The same as (5) but with a 5-year depreciation base.

Table 1 shows the relative changes to costs and margins, and the rates return for the foregoing conditions.

General Comments and Conclusion

An examination of the previous costs (which have been oversimplified with regard to whether they are fixed, variable, or mixed) indicates some of the points to consider:

a) The overall effect on profits, when considered with taxes and depreciation.

b) The volume of profit, as well as the percentage rate of return on investment.

c) The relative age of the plant and the level of original investment.

d) The profit position of the plant "today," as well as the near and long range picture.

e) The overall estimated supply of raw material compared to the useful life of existing and proposed equipment.

f) Manpower or wage savings as a single criterion. Normal alert management, generally speaking, will have been conscious of labor saving devices and practices. Where manpower savings are to be realized, any introduction of automation has to either increase output per man to the extent of the percentage of a crew reduction, or retain the same volume in finished throughout and physically remove the employee from the area and from the time clock.

g) Automation best succeeds when there are beneficial side effects which are measurable. The investigation of potentials for automation must include a careful review of other operations ahead and behind. First of all, to insure if they are affected and, second, if the effect is in the best interest costwise.

From the foregoing case, it can be concluded that the additional investment should be made only if the volume level is raised. The manpower saving alone does not justify the investment.

New Equipment Developments Point to Continuous Layup System[1]

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Let's take first things first! The continuous layup system can soon be a reality—but it demands the attention of the entire plywood industry.

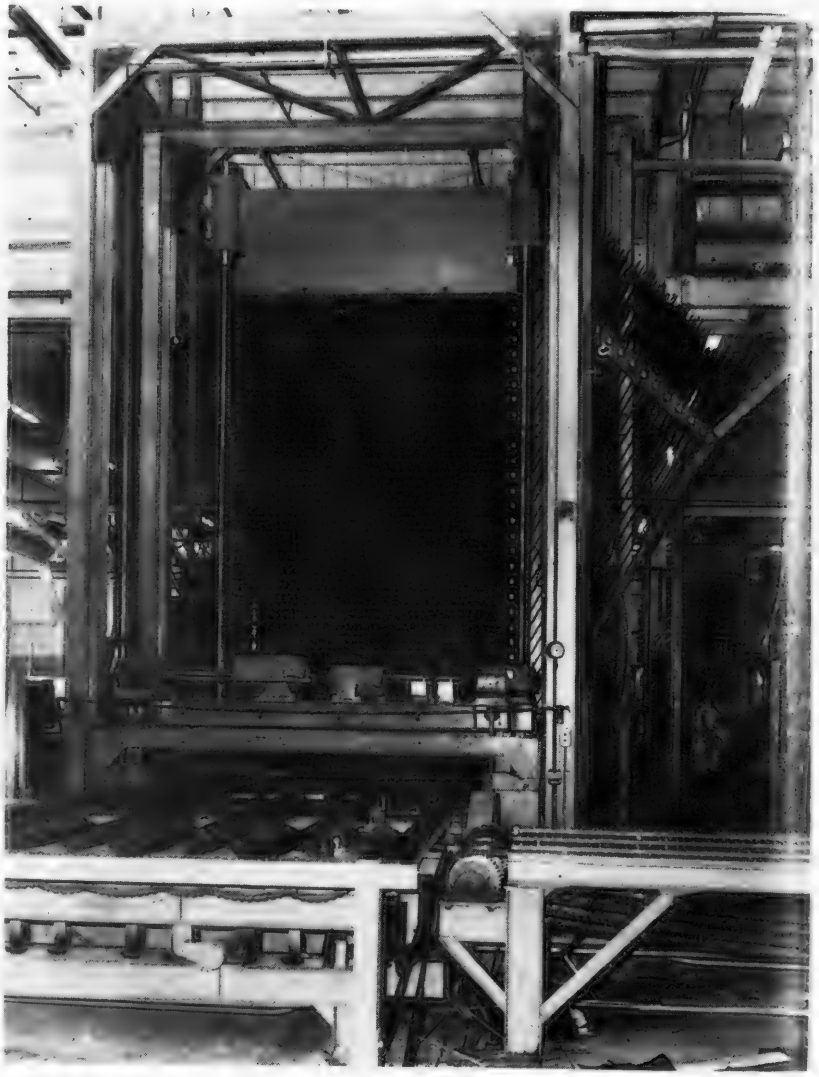

Fig. 1.—Automatic pressing unit consists of a 30-opening, 4- by 8-foot, side-loading unit with a simultaneous closing device.

AUTOMATION IN PLYWOOD HARDboard, or composition board plants is of particular interest to equipment manufacturers such as ourselves for the obvious reason of new potential equipment sales. Up to date, we have confined ourselves to several major equipment items in the finishing end, and as such are not concerned with the green end, drying, edge gluing, or machine finish. Until a few months ago, we were not concerned with veneer patching. In brief, then, this Company was primarily concerned with the press operation including the accessory loading and unloading and stacking equipment.

Approximately 3 years ago, after having looked at many plywood installations, and having witnessed what appeared to be the excessive waste of manpower in the handling of veneers through the mill, it was decided we would investigate the possibilities of automatic charger operation, assuming that continuous layup was an imminent possibility and further, that we had better be in on the ground floor when and if continuous layup became a reality. It was soon apparent that although the majority of people in the industry with whom we talked, were in agreement that continuous layup was of vital importance to the industry, there apparently was no possibility of continuous layup becoming a factor in the west coast mills for some time to come. For this reason, we postponed any further activity in our engineering department on this phase of plywood automation.

Just recently, certain developments have been made which have changed our thinking somewhat.

Continuous Patcher

The first item we would like to discuss in a preliminary way, is a continuous patcher we are presently building for two of the west coast mills under their joint venture with the initial installation to be located in Canada. This, as most of you are aware, is a patented process under license to the Plywood Research Foundation, using the Kimberly–Clark patents. Because this is the first unit of this kind, and will not be installed until this fall, certain detailed information must be withheld, and we trust you will bear with us if some questions remain unanswered. Basically however, we can advise concerning certain details regarding this equipment. The press of the continuous type which is designed to operate at 40 feet per minute and at 50 psi. The effective platen working area is 56 by 123 inches, with the temperature of the press plates will be up to 400° F. The reason for the established overall length of the

[1] Part of a panel discussion presented at Session XII, Glues and Gluing and Veneers and Plywood, FPRS 14th Annual Meeting, June 8, 1960 in Montreal, Canada; Approved for publication July 1, 1960.

press is twofold. First, laboratory tests indicated a 15-second cycle for curing the wood fiber patch. Second, based on the available D-grade veneer core to be upgraded, the production of this machine at 40 feet per minute was adequate.

Obviously, there has to be some means of filling all voids in the veneer, prior to pressing. This is being handled by more or less conventional vacuum forming process on a Fourdrinier screen with adequate provision for removing the excess fiber from the wound veneer; prepressing the patch by pinch rolls in the vacuum former prior to the transfer to make certain the patch remains within the veneer prior to depositing this veneer on the saw steel lower belt. The steel belt transports the dried veneer through the press section.

We had serious doubts concerning the economic aspects of a continuous press as compared to multi-platen units. In this particular case, a laboratory model was built and operated very satisfactorily with a very low coefficient of friction. This is one of the features of design which we would prefer not to disclose at this time.

It would appear from the preliminary studies that the continuous patching system will result in considerable saving to the fir plywood industry not only from manpower production costs of conventional patching devices, but also in upgrading the D-grade veneer.

We mentioned previously our interest in developing a completely automatic pressing operation when continuous layup was a fact. We first considered a theoretical system with the incoming conveyors on the right. Panels might, for instance, come off this line in a continuous form and be cut to size by a conventional flying saw, or they might come off in conventional layup size.

The individual panels would be cross transferred from the inline conveyor to one of the two indexing type charger units. As the charger continues to index up to receive the incoming panels, the other charger unit, which has now charged the press, is declining to the bottom of the pit and is cross-transferred approximately 10 feet on the bottom rails which will allow the declining elevator to return to the top position ready for charging the press when the charger, being indexed upward, is completely filled and is then cross transferred to the charging position. At the time the charger receiving the panels has reach the top rail sections, the second unit moves over directly underneath the first unit or the unit being charged, and when the loaded charger unit has moved away from the receiving position, then the indexing operation starts again, and the cycle is repeated.

Automatic Press

Although we first thought this would be a good arrangement for the conventional side-loading presses in spite of certain mechanical problems, a more recent development in automatic charging equipment has completely altered our thinking.

We recently installed two completely automatic pressing units for one of the larger sheathing manufacturers, and the press shown in Figure 1 is one of these duplicate units, a 30-opening, 4 feet by 8 feet, side-loading unit with simultaneous closing device, while the automatic loader is of the alternate indexing type. The complete installation consists of the alternate indexing, 30-opening charger, press, and indexing type unloading elevator with panel ejector, and an automatic hydraulic panel stacker. Although this installation was designed for completely automatic operation, because of certain problems with faces, the operation and manpower requirements are more or less standard with the industry today with two men feeding the charger, the panels being stacked at the glue spreader and transported to the loader by conventional conveyors with panels being loaded into the charger as it indexes automatically. When certain local problems have been overcome, the operation will eliminate all but one man at the press whose duties will only be concerned with checking for possible panel hang-ups.

When conventional glues are being used, it is better to stack the uncured panels at the glue spreader rather than to attempt to convey individual layups from the spreader to the automatic charger. This would appear to be a problem which could be resolved by any of the resin manufacturers. However, we believe it could be solved in the case of the 30-opening installation by utilizing a high speed prepress on the conveyor between the glue spreaders and the charger. It would of course be necessary to install a speed-up section to create a gap, but this is done normally in particle board and hardboard plants. Another possibility would be a continuous roll type press with sufficient temperature to set an uncured bond in the panel. Still another possibility would be stapling the layup at the back edges so as to eliminate the problem of face peeling into the charger. As a matter of information, some research has already been done on this, and perhaps the resin manufacturers can advise you in detail as to the type of resin required for this type of operation. Under the proposed arrangement, as the panels are laid up at the glue spreader, they will be transported individually from the glue spreader to the automatic charger and injected into the charger as it indexes by alternate flights. The unit will index in the following manner. Flight No. 2 will be charged first, then No. 4, No. 6, and up to No. 30. Then Nos. 29, 27, 25 etc. up to No. 1 will be changed where the unit is lined up with the press, and is ready for loading. The charger trays themselves are approximately 3 feet wider than the press platens, thus eliminating the chance of precure. When the press opens, the pushbars on all trays will advance and push all uncured panels forward approximately 3 feet so as to be in position to deposit on the press platens during the actual charger operation. At this time, the trays are forwarded by a conventional rack and pinion drive into the press, and the leading edge of these trays will push the cured panels into the self-declining indexing type unloading elevator. When the trays have advanced the proper distance into the press, the push bars advance simultaneously with the retraction of the trays and the uncured panels are deposited on the face of the press platen. As soon as the trays and the charger assembly have retracted sufficiently to clear the press, the push bar assemblies are retracted and the charger indexes down one flight and is ready to receive the next panel. The unloading elevator and panel stacker unit are quite conventional in design, with all panels being ejected from the unloading elevator at a common elevation onto a declining hydraulic stacker unit which normally has provisions for three complete press loads. When the declining panel stacker reaches the bottom position, a limit switch is tripped and the stacker unit rises to a point where the main platform is at the elevation of the off-bearing conveyor which may be either live roll or gravity roll type. At this point, an air cylinder tilts the stacker platform and the complete stack rolls off to the off-bearing conveyor for pickup by conventional fork lift trucks.

Press Operation

The press itself operates at extremely high speeds, with an approach and return speed of approximately 600 inches per minute and a pressing speed of around 50 inches per minute. During actual operation, the total time from the full open position to full tonnage on two 3/8-inch panels per opening, is only 17 seconds. Another feature, although certainly not as important to plywood as it may be to particle board and hardboard with heavier press plat-

ens, is the fact all plates are counterbalanced and the pressure on the panels is identical between the top and the bottom opening.

The arrangement just described would be ideally suited for any of the existing presses in the western plywood industry, which are of course all side opening. It would be less expensive from an installation and maintenance standpoint than the design which we originally considered when continuous layup first came into the picture. We believe, however, that once continuous layup is a reality, the industry should no longer be concerned with conventional 4- by 8-foot or 5- by 10-foot or even, as in one instance, a 6- by 12-foot press, but rather the presses should be of the end loading type and perhaps 8- by 16- by 20-foot opening. This would allow for better cut-up and eliminate a good percentage of the trim loss which we understand is around 12 percent on 4- by 8-foot panels. The loading and unloading equipment could be of conventional design, and we can envision no problems in this connection. Granted, the initial cost of a complete installation might appear high compared to say two 4- by 8-foot presses, but it would certainly not be double the cost of one unit if we were to furnish a 4- by 16-foot end loading unit.

We are frequently asked about radio frequency heating for plywood and particle board where single opening presses would be used. The companies who manufacture RF heating units feel that they are ideal for composition boards in thicknesses of ½-inch and over, and that reduced time cycles can be obtained in the press. These companies, however, indicated there is no appreciable advantage in reduction of cycle time on plywood. In fact, the power requirements on plywood are excessive, ranging from about 2.2 to 4 KW per square foot with the maximum power of course being used to heat the veneer. There are also other factors which must be considered in single opening RF heated presses, such as the necessary insulation and the shielding. From what we can learn to date, it would appear that RF heating is not a factor in plywood production.

When you consider the tremendously increased production of particle board in this country in the past few years, and the encroachment of composition boards into established plywood fields such as floor underlayment and ultimately sheathing, and particularly because of the severe mill price fluctuations of plywood, it would seem obvious everything possible should be done to reduce plant costs by automating plant equipment and utilizing lower grade logs. It would appear first things should come first, and the continuous layup should demand the attention of the industry. The finishing end has already been proven.

Wet-Web Gluelines Reduce Layup Cost[1]

H. M. PREUSSER
American-Marietta Co., Seattle, Wash.

Gluing systems that save layup labor and glue justify large investments in equipment. Mechanical panel layup plus a wet-web glueline system will reduce labor costs significantly.

THE ECONOMICS OF THE PANEL layup department of a typical fir plywood operation are primarily influenced by the costs for glue and direct labor. New panel layup and gluing techniques, such as the "wet-web" system, can reduce these costs.

Mr. Herstrom has established the overall costs of panel layup in Table 1 of his paper as follows:

Panel layup direct labor—$3.57/M feet, ⅜ inch
Glue cost (average)—$5.00/M feet, ⅜ inch

We will break these costs down further to point up those areas of cost which dominate and are the main targets for cost reduction.

Using a separately developed set of figures, we will consider an operation equipped as follows:

Press—24 opening, with loader, installed cost	$120,000
Spreaders—2, installed cost	22,000
Glue mixers (loft), installed cost	8,000
Total	$150,000

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We will use the following operational and accounting data:

1) Production, 45,000 feet core line (⅜ inch) per spreader, per shift. Monthly production of 5,400,000 feet ⅜ inch based on an average of 60 shifts per month.
2) Labor rate, layup personnel—$22.50 per day (including wages, benefits, taxes and paid non-working days).
3) Depreciation basis—10 year, straight-line.

Looking first at the operating cost imposed by the investment in major equipment we get:

$$\frac{\$150{,}000}{12\ (\text{months}) \times 5{,}400\ (\text{M ft.}) \times 10\ \text{years}} = \$0.23/\text{M feet } ⅜ \text{ inch}$$

Direct layup labor may be broken down as follows:

Function	No. of men 3 shifts
Press operators	6
Spreader crews	24
Glue mixers	3
Rustlers, checkers, fork truck, core saw and misc.	6
Total	39 men

The per M cost of this direct labor becomes:

$$\frac{39 \times \$22.50 \times 20\ \text{days}}{5{,}400\ (\text{M ft.})} = \$3.25/\text{M}$$

This figure is in reasonable agreement with the figure of $3.57 listed by Herstrom.

Glue Costs

A $5.00 *average* glue cost represents a rather high figure for the fir plywood industry but the percentage of exterior glued production may be assumed high in this case. In estimating, it would be appropriate to consider a $6.00 exterior glue cost and a $3.50 interior glue cost. An average cost of $5.00 would result if production were 60% exterior. A *minimum* cost case

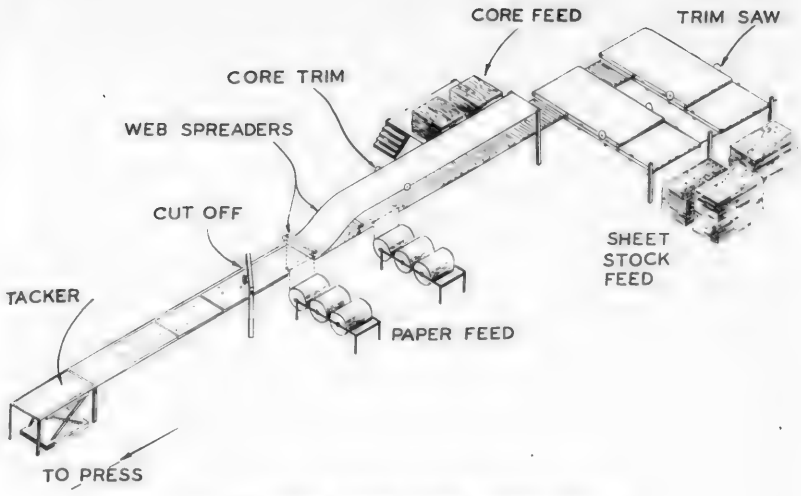

Fig. 1.—Layout of typical wet-web gluing system.

might be 40% exterior at $5.00 and 60% interior at $2.75 for an average cost of $3.65.

In review, it is obvious that the contribution to operating costs of the major panel layup equipment is very small compared to direct labor and glue costs. The return on investment must of course be considered.

Glue costs are an obvious area of interest for cost reduction. Of the other panel layup costs, labor cost of the direct spreader crew is by far the largest item.

As illustrated by Mr. Herstrom, the actual realization of manufacturing cost reductions may be subject to certain limits. We will suppose, using the figures in his Table 2 that the mill can produce the desired 7,000,000 feet of ⅜-inch board without increasing the labor force if a press bottleneck can be "broken". We might increase press capacity from 6,500,000 to 7,000,000 feet by using a glue having roughly a 15 percent reduction in press time. Such a glue might be available at a 10 percent glue cost premium—$0.50/M, ⅜ inch. In arriving at a new manufacturing cost (Table 2 of Mr. Herstrom's paper) we add $0.50 to obtain $59.63/M, ⅜ inch basis. Depreciation remains the same at $4.23. Net margin is $12.14 and annual gross profit less taxes is $510,000, giving a return on investment of 15.5 percent.

The proposed investment was not justified without increased production. Based on the stated assumptions, an increase in variable costs (use of a premium fast-setting glue) provided a sound financial basis for the investment.

This case study illustrates that glue costs and other panel layup costs do not always have to be reduced to improve profits and return. It also strongly emphasizes the importance of having production elements in balance.

Wet-Web Systems

Mr. Stensrud has described the use of dry film adhesive and several automatic panel assembly techniques based on the use of the film. A new approach to automatic panel assembly is referred to as the wet-web glueline system. This system, as the name implies, involves direct application of wet adhesives to a carrier sheet or web and immediate application of the web to the veneers (equivalent to spreading). This new process is currently being put into limited commercial production in a west coast Douglas-fir plywood mill and will be generally available under license after the first commercial operation is established.

The wet-web glueline not only lends itself to automatic or mechanical layup, but because of the delicate nature of the wet carrier, virtually depends on such developments.

The question may be fairly asked—why use a wet system? The wet sheet is difficult to handle and the resultant panel assemblies must be pressed soon after the glue is applied. The answer lies primarily in cost factors—both direct glue cost factors and indirect costs resulting from differences in pressing speed.

Generally speaking, it is not feasible to dry very high molecular weight water-borne adhesives, such as proteins, phenolic resins and urea resins, prior to the actual gluing step. Such materials, in effect, become non-wetting and non-penetrating. They develop such strong cohesive forces during the drying step that even rewetting with water will not ordinarily promote sufficient adhesive capability. Predried phenolic gluelines are practical (as evidenced by the dry film glue technique), but the resin used in such applications is necessarily characterized by low molecular weight and subsequent slow rate of cure. In many applications this characteristic is not important. In the softwood plywood industry, the emphasis on low glue costs and fast pressing is great. High molecular weight water-borne adhesives dominate throughout the softwood plywood industry. Thus, another justification for the wet-web system is that it permits the use of desirable high molecular weight adhesives with a carrier or web process of glue application.

Figure 1 illustrates one of several basic wet-web gluing configurations. Starting at one end of the machine, sheet stock is fed perpendicular to the motion of the main conveyor. In completing this transverse motion the sheets (face, backs and centers as required) are end trimmed to a dimension slightly greater than finished panel size. When the required sheets are over the main conveyor they are accelerated down the conveyor, end to end. When 3-ply panels are being made, paired backs and faces move consecutively toward the glue applicator. In the case of 5-ply panels, paired backs and faces alternate with centers. For 7-ply the paired back and faces are followed by a center which is followed by another center, etc.

The sheets pass under a wet-web spreader which lays down the web carrier, impregnated with glue.

Above the sheet stock section of the conveyor is a core crowder. Dry core is fed, end trimmed, and carefully let down on the first wet-web. Immediately thereafter a second wet-web is laid on top of the core.

The next step is parting of the continuous line of core at the juncture of the sheets. This is accomplished with a flying saw. At this point we have one of two "assemblies" as illustrated in Figure 2. In making 3-ply panels, assemblies are created and conveyed along in the order A-A-A-A etc. For 5-ply panels, the order is A-B-A-B etc. For 7-ply panels, the order is A-B-B-A-B-B-A etc. Any reasonable odd number of plies may be used in a single panel.

The "assemblies" are accelerated to an automatic stacker that lays the "assemblies" one on top of another until a panel, group of panels, or "press charge" of panels is created. The number of panels stacked before removal to the pressing area is dependent on the nature of the press loading system. When an indexing loader is used the panel package removed from the stacker will be package that enters one deck of the loader.

Technical features of the wet-web glueline that warrant emphasis are: 1) Spread control can be excellent. The mechanics of control and measurement are simple. 2) The spreaders are clean (free of the usual sawdust, knots, etc.) and because of rapid system replenishment, the way is opened to use glues having a limited pot life and faster pressing time; 3) Gluing efficiency is high. Because of guaranteed spread control, lower spreads are used; 4) The cost of paper is substantial—being in the range of $1.15/M, 3/8-inch basis. This cancels most of the *direct* glue savings, therefore, we must look elsewhere to justify an installation.

The carrier, web or film systems are labor saving devices. The wet-web layout shown in Figue I is designed to use one half the spreader crew labor normally required—a saving estimated at about $1.25/M feet of 3/8-inch board. Elimination of glue mixing, use of only one press operator and extensive use of automation in feeding veneer could increase total labor saving to as much as $1.60 M, 3/8-inch.

Carrier webs of film systems are uniquely able to accommodate direct crowded core feeding. This technique plus sheet stock end trimming—easily automated due to the line flow of veneer—lead to a saving in core which is estimated at $0.45/M, 3/8-inch. (Core value $30.00), 3/8-inch basis, as the spreader; 38 percent of stock as core.) These systems also lead to reduced veneer compression because of reduced concentration of moisture at the glueline and as a result of the carrier sheet thickness. A 2 percent saving of veneer is predicted, resulting in a $0.55/M, 3/8-inch saving based on a green veneer cost of $27.60/M 3/8-inch.

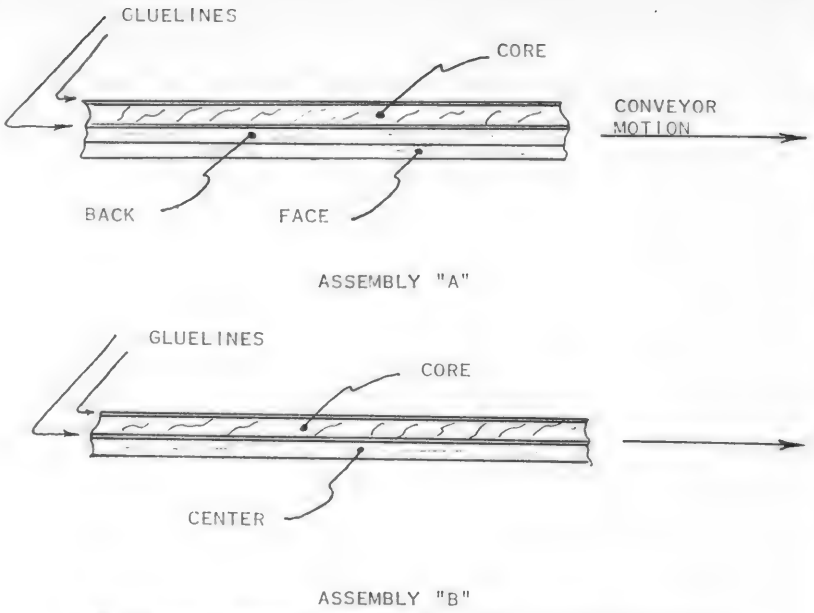

Fig. 2.—Basic assemblies of plywood layup with wet-web gluing system.

Equipment for the wet-web system will range in cost from about $35,000 to $100,000 depending on the type of production, production rate, and degree of automation used. For a two-spreader system as shown in Figure 1, the depreciation cost (10-year, straight-line) would be about as follows:

$$\frac{\$85{,}000}{9{,}300\ (M3/8) \times 12\ \text{months} \times 10\ \text{years}}$$

= $0.076/M feet, 3/8-inch basis

Overall panel layup production cost savings offered by use of the "wet-web" system are estimated to range from $1.50 to $2.50/M, 3/8-inch depending on the plant production program and the extent of automation.

Summary

In the panel layup department of a fir plywood mill the major costs are glue costs and direct labor. The overhead cost burdens of major equipment are quite small comparatively. Gluing systems that save layup labor and glue can justify relatively large investment in equipment. Substantial panel layup labor savings are within reach at the present time, based on mechanical panel layup and automation—these in turn being based on dry film glue and the "wet-web" glueline system. Substantial wood savings and other benefits are a by-product of these new techniques.

NATIONAL FOREST PRODUCTS WEEK
OCTOBER 16-22 1960

Prediction of Plywood Bond Durability[1]

P. L. NORTHCOTT and H. G. M. COLBECK

Vancouver Laboratory, Forest Products Laboratories of Canada

THE MAJOR OBJECTIVE OF THIS research was to demonstrate whether or not it was possible to predict the service life of plywood from its performance when subjected to accelerated weathering treatments in the laboratory. If found possible, this method could be used to estimate the service life of plywood made with new glues, or with new uses of old ones. To be most useful, the accelerated weathering treatments should not require more than a few weeks.

The theory was that bonds, even such notably inert ones as phenolic resin bonds, continue to lose strength due to fatigue, chemical, or other effects when subjected to repeated reversals of stress of sufficient intensity. It was reasoned that major causes of such reversals of stress included swelling and shrinking of the wood and glue due to changes of moisture content and temperature.

Such a pattern of behavior was first demonstrated for plywood subjected to the severe treatment provided by a series of boiling and drying cycles (4 hours of boiling in water; 20 hours of drying). This work was then expanded to see if a correlation could be established between the fatigue induced by cyclical boiling and drying and continued exposure to the weather.

The results of 5 years of exposure (on both painted and unpainted panels) seem to confirm the theory that it is possible to predict the service life of plywood from its performance when subjected to suitable accelerated weathering treatments and the necessary tests for bond quality.

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It is planned to remove the next set of panels from the test fence in 1964, at which time it is anticipated the correlations that have been indicated will be confirmed.

Results of accelerated-weathering tests were compared with the results of long-term exposure tests of plywood. A correlation is demonstrated for four phenolic resin adhesives, and it is shown how this information can be used to predict the service life of plywood.

The project was commenced 5 years ago to test the theory that the service life of plywood bonds could be predicted from the results of relatively short-term "accelerated weathering" tests. The "accelerated weathering" method chosen was repeated boiling and drying of the plywood (4 hours of boiling and 20 hours of drying per cycle). The service condition selected was exposure to the weather on a fence facing south in a field at the University of British Columbia, Vancouver, B.C. Two series of panels were so exposed, one series painted and the other unpainted. The strength of the plywood was measured periodically: first in the untreated condition; secondly, after 1, 2, 4, 6, 10, and 20 cycles of boiling and drying; and thirdly, (both painted and unpainted) after 6, 11, 32, and 56 months of exposure to the weather. It is planned to measure the strength after further exposures of 5 and 15 years. The plywood used in this study was 3-ply, made from 1/10-inch thick Douglas-fir heartwood veneers bonded with hot-press phenolic adhesives some of which, by reducing the resin content, were purposely made "weaker than the wood."[2]

Previous work (4)[3] had yielded the pattern of curves presented in Figure 1. The most important information provided by these data are: a) that all four hot-press phenolic glues continued to lose strength after successive cycles of boiling and drying, b) that all four glues lost strength much faster than wood (2,3), and c) that the low resin-solids or "weaker than the wood" bonds lost strength much more rapidly after increasing cycles of boiling and drying than the 27½ percent resin solids (Exterior Grade bonds).

It was reasoned that the continuing loss of strength after successive cycles of boiling and drying, in the case of phenolic resin adhesives which are extremely insoluble in water when fully cured, was attributable to the fatigue effects of the reversals of stress induced by the swelling and shrinking of the wood as it was wetted and dried. It was probably also due to chemical degradation of the wood at the wood-glue interface where excess caustic from the glue would favor such action.

It was further reasoned that similar effects would probably be induced in plywood in service, although at a much slower rate, by changing atmospheric conditions—the more severe the exposure, the more rapid the degradation.

If these assumptions are correct, then it seemed probable that a correlation could be established between the rate at which a bond loses strength in service and the rate of strength loss in accelerated weathering. Further it appeared that this correlation could be used to predict the service performance of a new glue when subjected to the cyclic

[1] Presented at Session IX, Glues and Gluing, FPRS 14th Annual Meeting, Montreal, Canada, June 7, 1960.

[2] It is realized that the phrase "weaker than the wood" is very inexact but it seems to express the intent better than a more lengthy statement.

[3] The numbers in parentheses refer to the literature cited at the end of this report.

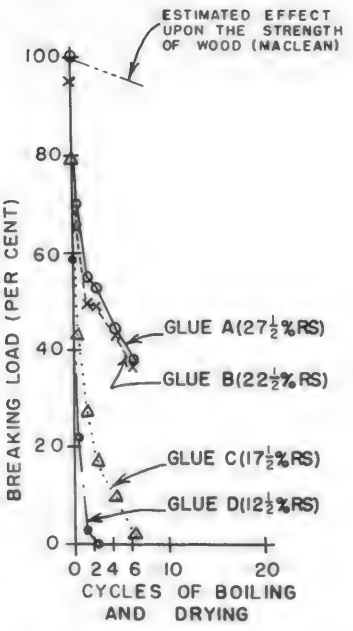

Fig. 1.—Relationship between percentage of breaking load, percentage of resin solids, and cycles of boiling and drying. (Each point is the average of 8 tests.)

boiling and drying tests. It was to test these hypotheses that the project was established.

The working plan and initial phase of the research were set up as a long-term project at the Vancouver Laboratory in 1954. As a student assistant, W. J. Pearson described this project in a prize winning student essay entitled "Preliminary Report on a Proposed New Method of Estimating the Service Life of Exterior Grade Plywood" and published in the Forest Products Journal, Vol. VI, No. 6, 1956. In the interests of brevity the material contained in Pearson's article will not be repeated here.

Design of Project

A factorial design was used with the following factors:

Factor a: Three exposure conditions to which the plywood was subjected: one series of panels having been subjected to cyclical boiling and drying (each cycle consisting of 4 hours of boiling in water followed by 20 hours of drying at 170°F. in a forced circulation oven):[1] two series of panels exposed to the elements on a fence facing south, one series being painted and the other unpainted.

[1] Further work has indicated the necessity of including several types of treatments, such as cyclical soaking in cold water and drying, cyclical boiling and drying, and exposure to pathogens in order to derive optimum accuracy from an accelerated weathering test.

Factor b: Four phenolic resin glues: "A" with 26½ percent resin solids, as used in the manufacture of Exterior Grade plywood, "B" with 22½ percent, "C" with 18½ percent, and "D" with 12½ percent resin solids.

Factor c: Seven severities of each exposure, ranging from zero to 20 cycles of boiling and drying, and from zero to 20 years exposure to the elements.

Factor d: Ten trees, veneer from each being included in each of the above factorial combinations.

Factor e: Fourteen 1-inch square specimens per panel, sawn along a diagonal of each 1-foot square panel (one per tree for each of the above treatment combinations) to provide evidence that the edges of panels are, or are not, subject to greater degradation than the centers of panels.

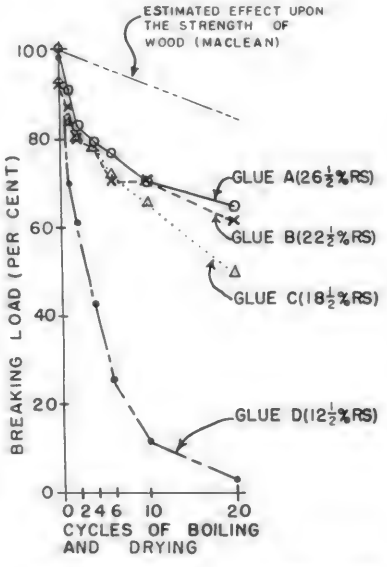

Fig. 2.—Relationship between percentage of breaking load, percentage of resin solids, and cycles of boiling and drying. (Each point is the average of 28 tests on one panel from each of 10 trees; i.e., 280 tests.)

Factor f: Two glue lines per specimen, one with tight-to-loose and the other with loose-to-loose veneer faces.

Factor g: Two estimates of bond quality per glue line: (a) the breaking load, and (b) the percentage of wood failure. In addition, the dimensions, the specific gravity, and the percentage of moisture content at test were measured for each specimen.

The complete design involved testing 23,520 glue lines and measuring 4 properties of each glue line.

Variability

One of the disturbing features concerning this work has been the excessive variability in both breaking loads and percentage of wood failures, particularly in the plywood which was exposed to the weather and which, of necessity, was tested by different personnel over a period of 5 years. This is particularly disturbing in view of the large size of the sample and because of the thoroughness of the work. In stating that the work was done thoroughly, it is not intended to imply that the workmanship was perfect, because various deficiencies have been mentioned, but the planning and statistical design and documentation were thorough within the abilities of the researchers. Some of the excessive variability is a result of unforeseen factors such as: the glues increasing in strength during the 6- to 3 month exposure periods, when the available information had indicated that they would lose strength; the necessity to use longer press times to cure the lower resin-solids glue and the fact that 4-foot panels could not be pressed with the 12½ percent resin-solids glue although 1-foot square panels could be. Undoubtedly some of the variability is attributable to changing personnel, although the details of research and the training of personnel were designed to minimize this. Another part of the variability appears to be due to changes in the hygroscopic properties of the wood with prolonged exposure to the weather. The evidence which is most disturbing however, is the apparently excessive variability between panels which were planned to be matched. The nature of the matching was that four panels, each

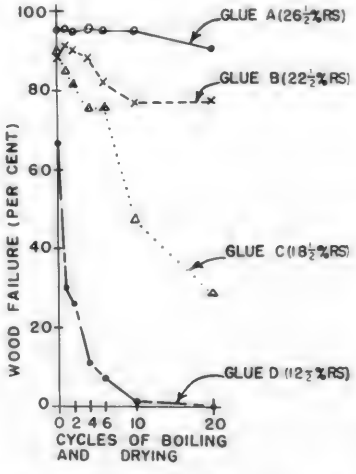

Fig. 3.—Relationship between percentage of wood failure, percentage of resin solids and cycles of boiling and drying. (Each point is the average of 28 tests on one panel from each of 10 trees; i.e., 280 tests.)

4 feet by 8 feet, were manufactured from consecutive sheets of veneer from one tree, one panel being manufactured with each of the four glues. Each of these panels was then sawn into 1-foot square subpanels which were randomized and allocated to the different treatment combinations. Replication was provided for by repeating the process with veneers collected from each of 10 different trees. The process must have been partially successful because some definite tree effects are discernible, but the variability between 1-foot square sub-panels within each 4-foot by 8-foot sheet in such properties as specific gravity and severity of lathe checks, which are known to influence both breaking load and wood failure seems largely to have negated the benefits of using the principle of matching panels. The deduction which comes most readily to mind regarding sampling and design of future experiments is that the matching of wood samples with a useful degree of accuracy is impractical and that the maximum in randomization should be the goal. In other words, each sub-sample should consist of the minimum number of specimens per panel and the maximum number of panels necessary to obtain the required probabilities.

Because the variability in the breaking load and percentage of wood failure of the panels exposed to the weather was much greater than anticipated, an incomplete examination was made for assignable causes in the hope that corrections for these would reduce the error variance and increase the significance of the differences. The roles

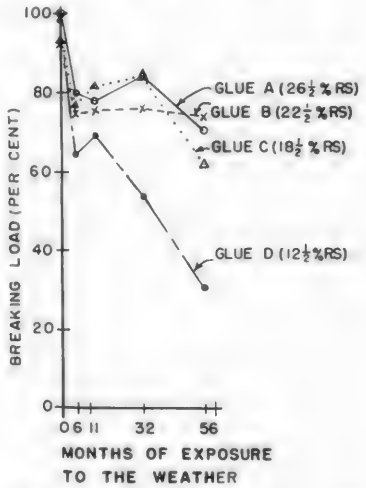

Fig. 4.—Relationship between percentage of breaking load, percentage of resin solids, and months of exposure to the weather for unpainted panels. (Each point is the average of 28 tests on one panel from each of 10 trees; i.e., 280 tests.)

of specific gravity of individual specimens within a panel, specific gravity between panels, moisture content at test, tight-to-loose vs. loose-to-loose faces, edge effect or position of the specimen within the panel, and the severity of lathe checks in increasing the error variance were studied on the specimens from selected treatment combinations. It soon became evident that, the error variance would be appreciably reduced by taking these factors into account. The adjustments required, however, were rather complex, as they were influenced by such factors as the glue, the type of treatment and the severity of the treatment, and the necessary analyses were beyond the resources of the researchers at this time. Therefore, no attempt is being made to make a complete statistical analysis of these data, but more complete analyses are planned, possibly after the

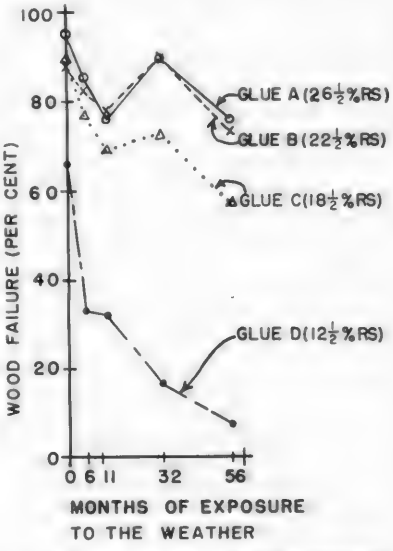

Fig. 5.—Relationship between percentage of wood failure, percentage of resin solids, and months of exposure to the weather for unpainted panels. (Each point is the average of 28 tests on one panel from each of 10 trees; i.e., 280 tests.)

next set of specimens is removed from the exposure fence and tested in 1964.

For the purposes of this report, Factors "e" and "f", and the effects of specific gravity and percentage of moisture content at test will be included in the error variance; although, in more complete analyses, they would be considered as treatments, and the error variance would be reduced accordingly.

Results

The pattern of information which was expected from the cyclic boiling and drying or accelerated-weathering treatment is illustrated in Figure

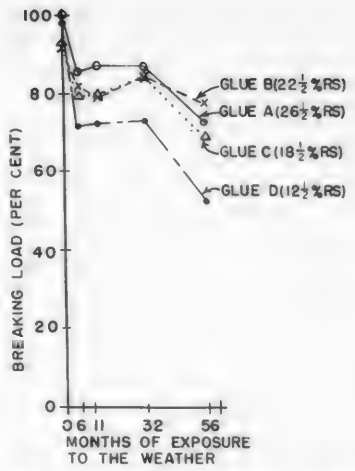

Fig. 6.—Relationship between percentage of breaking load, percentage of resin solids, and months of exposure to the weather for painted panels. (Each point is the average of 28 tests on one panel from each of 10 trees; i.e., 280 tests.)

1, which is Pearson's Figure 1 plotted to a scale more suitable for comparison with the other figures of this paper. The interpretation was discussed in the introduction.

The pattern of information obtained is presented in Figures 2 to 7 inclusive, and, with some exceptions, fulfilled the expectations. Comparing the cyclical boiling and drying data of Figure 2 with Figure 1, the patterns of results are similar but the absolute strengths for the same number of boiling and drying cycles are different. As anticipated, all bonds lost strength after successive cycles of boiling and drying, and separation of the bonds was effected by the most severe treatment. The separation of the glues in Figure 2, particularly Glue C, was not as good as in Figure 1. There are several logical reasons for the differences in the absolute valuse and for the poorer separation of the glues. The first is that the veneers in Figure 2, being only half as thick as those in Figure 1, were only capable of exerting half the force on the glue lines and were correspondingly less effective in degrading the bonds. The second is that Glue A in Figure 2 had 1 percent less resin solids than Glue A in Figure 1, while Glue C in Figure 2 had 1 percent greater resin solids than Glue C in Figure 1, so one would expect somewhat less separation between Glues A, B, and C in Figure 2.

The average wood failure percentages for these specimens are presented in Figure 3. As with the breaking loads, the greater the number of cycles, the lower the wood failure. This effect is very slight, but it is definite in the case of Glue

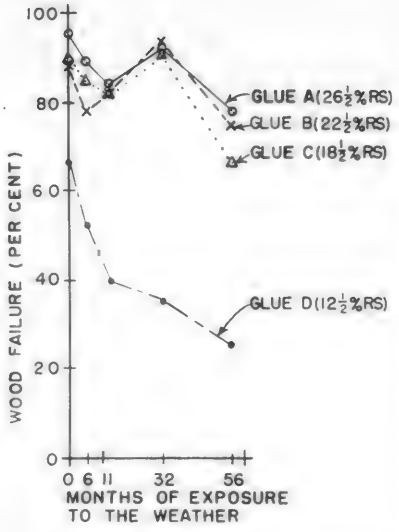

Fig. 7.—Relationship between percentage of wood failure, percentage of resin solids, and months of exposure to the weather for painted panels. (Each point is the average of 28 tests on one panel from each of 10 trees; i.e., 280 tests.)

A and very pronounced in the cases of Glues C and D. The separation of the glues is striking. This emphasizes a point which has been observed several times in the past (4, 6), namely, that percentage of wood failure seems to be much more sensitive to initial bond degrade than breaking load, providing it is bond degrade that is being observed.

The effect of exposure to the elements on the strength of unpainted plywood is set forth in Figure 4. After 56 months of exposure, the plywood exhibits the anticipated pattern of reduced strength in relation to increased exposure. However, the increase in strength of the glues from 6 to 12 months to 32 months exposure was quite unexpected. Inasmuch as the curves of Figures 5 to 7 follow the same pattern, it appears that this hump in the curves is not due to random variation but is due to some systematic process, such as an increase in bond strength, or relaxation of internal stress, during this exposure. Independent evidence is available from cycling-to-delamination tests supporting the increase in strength theory, and indicating that it is probably due to continuing cure of the adhesives in service up to approximately 3 years. The evidence referred to was that hot-press phenolic-bonded plywood which required approximately 20 cycles to delaminate when tested within 1 or 2 weeks after manufacture did not delaminate with 200 cycles when tested 1 year after manufacture.

Figure 5 presents the wood-failure data for the unpainted panels exposed to the weather. As in the case of the accelerated weathering tests (Figures 2 and 3), the wood-failure data have been superior to the failing-loads data in separating the glues in the order which one would anticipate from consideration of the percentage of resin solids. Comparing Figures 3 and 5, it appears that exposure to the elements has had a different effect than boiling and drying cycles in reducing the wood failure. The cyclical boiling and drying treatment seems to have had less tendency than exposure to the elements to reduce the wood failure of Glue A, about the same tendency with Glue B, and much greater tendency to reduce the wood failure in the cases of Glues C and D. If these indicated tendencies are due to real effects, then they act to the advantage of the evaluator of bond quality; i.e., the repeated boiling and drying treatments accentuate the differences which will occur in service.

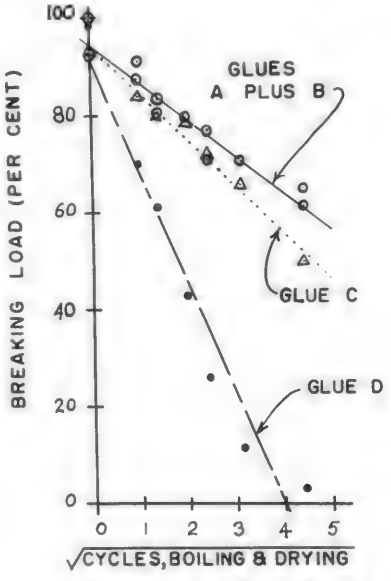

Fig. 8.—Relation between percentage of breaking load, percentage of resin solids, and the square root of cycles of boiling and drying. (Each point is the average of 28 tests on one panel from each of 10 trees; i.e., 280 tests.)

Now, comparing the curves of Figure 5 with those of Figure 3, and Figure 4 with Figure 2, there seems to be a distinct possibility of predicting the bond quality behavior of unpainted plywood exposed to the elements (Figures 5 and 4) from the behavior of the plywood bonds when tested after a series of boiling and drying treatments (Figures 3 and 2). This was the major objective of the research and, in spite of many shortcomings in the work, most of which can be rectified in future work, it appears to have been successful.

What has been said for unpainted plywood exposed to the weather can be repeated for paint-protected plywood similarly exposed, with the difference that, as anticipated, there has been even less separation of the glues (see Figures 6 and 7). The paint, by retarding the movement of moisture, probably reduces the frequency and severity of the reversal of stress which act to rupture the bonds.

Prediction

In order to be able to predict the service life of a bond in a particular type of service, such as exterior exposure, it seems necessary to demonstrate a correlation between the strength behavior under the chosen accelerated weathering procedure and the strength behavior under the chosen service conditions for each of several glues covering a range of bond qualities from the best available to those which would be unsatisfactory. It should then be possible to use this information, plus the performance of an unknown glue used with a comparable type of joint to predict the service life of the bond with the unknown glue.

Such a series of correlations exists between the data of Figure 2 and Figure 4, and another similar series between the data of Figure 2 and Figure 6. These correlations are improved by ignoring the humps at 32 months in Figures 4 and 6 on the evidence and theory that they are attributable to increasing cure of the glue in service and would not have appeared had the glues been fully cured during manufacture. However, these data were in an inconvenient form for correlation analyses, so a $\sqrt{x}$ transformation was adopted with which the data were plotted as

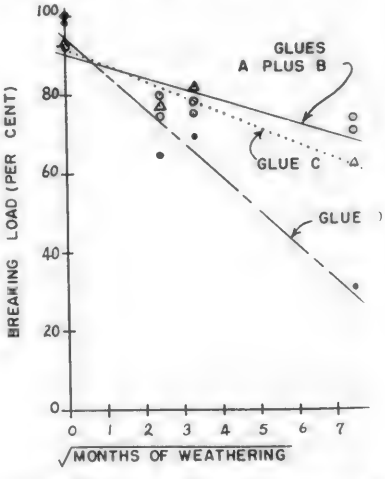

Fig. 9.—Relation between percentage breaking load, percentage of resin solid and the square root of months of exposu to the weather for unpainted panels. (Eac point is the average of 28 tests on or panel from each of 10 trees; i.e., 280 tests.

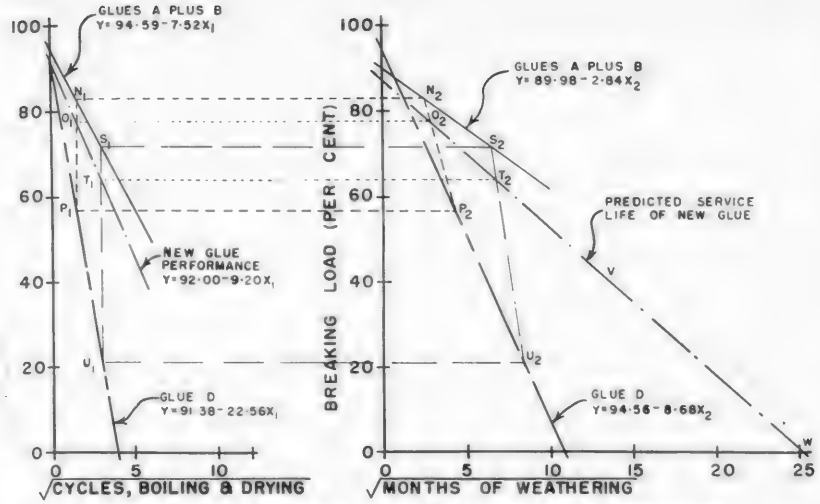
GLUES A PLUS B
Y = 94·59 - 7·52X1
NEW GLUE PERFORMANCE
Y = 92·00 - 9·20X1
GLUE D
Y = 91·38 - 22·56X1
GLUES A PLUS B
Y = 89·98 - 2·84X2
PREDICTED SERVICE LIFE OF NEW GLUE
GLUE D
Y = 94·56 - 8·68X2
BREAKING LOAD (PER CENT)
√CYCLES, BOILING & DRYING
√MONTHS OF WEATHERING

Fig. 10.—Graphical method of predicting the service life of plywood made with a new glue, or new construction.

straight lines with reasonable accuracy (See Figures 8 and 9). Regression lines were calculated for each glue for each treatment combination.

The regression of percentage of breaking load upon the square root of the number of cycles of boiling and drying for each glue are plotted in Fig. 8. The regressions of percentage of breaking load upon the square root of months of exposure on the test fence for unpainted panels for each glue are plotted in Figure 9. Because the differences between the breaking loads of Glues A and B were not significant, they are combined. The regression coefficients, means, and standard errors of estimate are summarized in Table 1. The significances of the differences between the regression coefficients, and the differences between the means of the regression lines for the different glues, for each series, are given in Table 2. It is anticipated that the levels of significance will increase after the next sample is tested in 1964. It must be emphasized that, while the differences between the breaking loads of Glues A and B were not significant at the usually accepted level of statistical significance (and were combined for ease of presentation), the evidence is provided by this research that a real difference does exist between the glues, and that Glue B (22½ per cent resin solids) will not produce as durable plywood as Glue A 26½ per cent resin solids), which was the accepted standard of adhesive for Exterior Grade plywood in 1954 when the research was commenced.

A graphical solution to the problem of predicting the service life of plywood made with a new glue, from the results obtained from relatively short-term laboratory tests, is presented in wood made with a new glue, from the Figures 10a and 10b. Glue D and the combined data of Glues A plus B are used to represent the known performance of two glues with a fairly wide range of durability, and a hypothetical "new glue" is used to illustrate the method. The fact that the hypothetical new glue approximates Glue C is purely coincidental.

Graphical Solution

1. Having subjected the new glue to the same series of boiling and drying treatments and strength tests to which the two known glues had been subjected to provide the data for Figure 8, the first step is to plot the linear-regression lines of percentage of breaking load over the square root of the cycles of boiling and drying for the two known glues and for the new glue (Figure 10a).

2. The second step is to plot the linear regressions of percentage of breaking load over the square root of months of exposure to the weather for the established performance of the two known glues as in Figure 10 b.

3. Erect a vertical line N_1,O_1,P_1 at a suitable value of X_1 (suitable for the optimum positioning to the point O_2).

4. Project horizontal lines from N_1 to N_2 (Glue A plus B), and P_1 to P_2 (Glue D).

5. Join N_2 to P_2.

6. Project a horizontal line from O_1 to intersect N_2P_2 at O_2. This is one point on the predicted performance line of the new glue.

7. Repeat steps 3 to 6 inclusive with the Figure $S_1T_1U_1U_2T_2S_2$ to establish the second point T_2 on the predicted performance line for the new glue.

8. Join points O_2 and T_2 and extrapolate to points V and W, or any similar point desired.

9. The value of X_2 at point W, when squared (i.e. $25^2 = 625$ months or 52 years) is the estimated average time for this particular plywood construction made with the new glue to delaminate. The value of X_2 at point V, when squared (i.e. $13.6^2 = 185$ months or 15.4 years) is the estimated average time for the strength of the plywood bond to reduce to 40 per cent of its initial strength. Similarly, an estimate can be obtained for any other desired residual strength.

It must be emphasized that the estimates indicated above are of the average life of the plywood to reach the stipulated condition and that approximately one-half of the plywood will reach that condition in a considerably shorter time. If desirable, it seems feasible to estimate the standard error of the regression coefficient for the predicted performance line from the standard errors of the other regression lines, and to use this to estimate the service life within any chosen confidence limits.

Industry Standard

Advantage will be taken of the opportunity to interpret the data in terms of the Douglas-fir plywood industry's accepted method of estimating bond quality—the percentage of

Table 1.—LINEAR REGRESSION STATISTICS FOR FIGURES 8 AND 9

Glue	Statistic	Regression of %BL upon the square root of cycles of boiling and drying (Figure 8)	Regression of %BL upon the square root of months of exposure to the weather (unpainted plywood (Figure 9))
Glues A and B 26½% and 22½% resin solids	b_{yx}	7.52 (0.001)*	2.84 (0.050)*
	$\bar{y}$	79.03	80.59
	S_{e^2}	9.80	41.57
	N	14	8
Glue C (18½% resin solids)	b_{yx}	— 9.49 (0.001)	— 3.96 (0.050)
	$\bar{y}$	74.61	78.55
	S_{e^2}	4.28	18.26
	N	7	4
Glue D (12½% resin solids)	b_{yx}	—22.56 (0.001)	— 8.68 (0.050)
	$\bar{y}$	44.67	65.80
	S_{e^2}	80.38	55.10
	N	7	4

*Note: The figures in parentheses indicate the statistical significance of the regression coefficients (0.001 very highly significant; 0.050 significant).

Table 2.—LEVELS OF SIGNIFICANCE OF THE DIFFERENCES BETWEEN REGRESSION LINES FOR FIGURES 8 AND 9

	Figure 8		Figure 9	
Regressions	Difference between slopes	Difference between means	Difference between slopes	Difference between means
Glues A plus B vs Glue C	0.050	NS	NS	NS
Glues A plus B vs Glue D	0.001	0.001	0.010	0.010

Note: 0.001 very highly significant; 0.010 highly significant; 0.050 significant; and NS not significant.

wood failure developed in plywood shear specimens when tested after boiling, drying and boiling (9). Referring to Figure 3, the percentage of wood failures of specimens which were broken after two cycles of boiling and drying will be used although they were not quite identical with those used in industry. One difference is that the wood failures were read from cleavage specimens rather than from plywood shear specimens, and another difference is that the specimens were tested dry after two cycles of boiling and drying rather than tested wet after the second boiling. The percentage of wood failure ratings for Glues A, B, C, and D are 94.7 per cent, 90.3 per cent, 81.2 per cent and 26.0 per cent.

Figure 11 presents the relationships between the percentage of breaking load, percentage of wood failure (after two cycles of boiling and drying which approximates the industry standard of bond quality), and cycles of boiling and drying, for each of the four glues. Figure 12 presents the same kind of data related to months of exposure to the weather. These curves and those of Perkin's (Figures 9 and 14) (8) tell essentially the same story—Perkins' in terms of the percentage of panels without visible delamination, and these in terms of the residual strength of the plywood.

Without going into detail, attention is directed to the fact that the British plywood industry, which manufactures plywood from a wide range of species, rates bond quality on what is essentially the percentage of wood failure observed when the panel is knifed in a standard manner (1).

It may seem that we are advocates of the percentage of wood failure method of estimating bond quality, and we admit to being greatly impressed by the potential of this method. However, there are several factors which require more extensive investigation before wood-failure methods can be used universally with confidence. One is to determine to what extent the correlation between wood failure and bond quality is affected by the different factors which contribute to low wood failure. Another, and extremely important factor requiring attention, is the development of a universally acceptable standard of percentage of wood failure and a method of teaching this standard and insuring that readers of wood failure conform to the system. The Douglas Fir Plywood Association (8) which first developed a method, use kits of standardized specimens which they circulate from reader to reader for training purposes and to "keep their

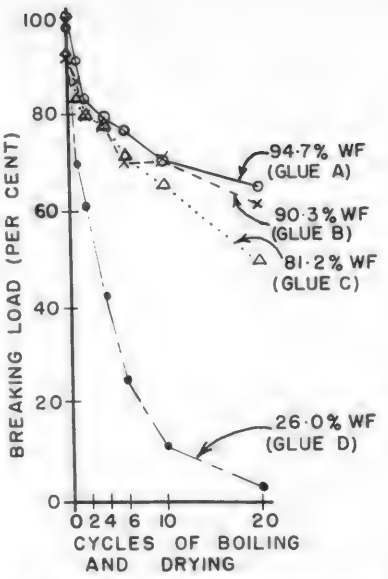

Fig. 11.—Relationship between percentage of breaking load, percentage of wood failure after 2 cycles of boiling and drying, and cycles of boiling and drying, for each glue.

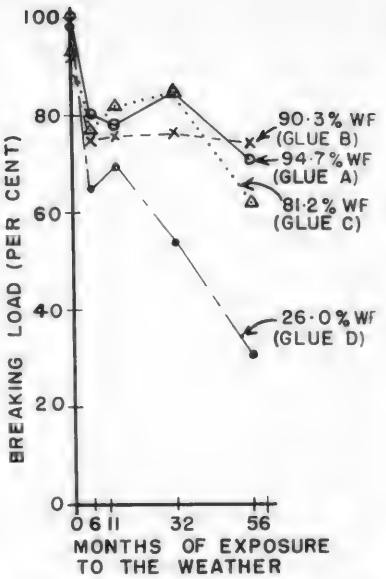

Fig. 12.—Relationship between percentage of breaking load, percentage of wood failure after 2 cycles of boiling and drying and months of exposure to the weather, for each glue.

eye in". The standard is an arbitrary one that was established by the most experienced people in this field at the time the method was developed and adopted. Other things being equal, it is really a small step to expand their system to include all interested agencies and people. It is understood that the American Society for Testing Materials is giving attention to this problem and probably will promote the necessary research to fill in the gaps in knowledge and to write a specification. Perhaps as more concentrated thought is brought to bear on this topic, a better method than that outlined will be developed. For a more detailed discussion of certain aspects of percentage of wood failure as an estimate of bond quality, it is suggested that items (5) and (7) be read.

Summary

A brief description is given, and reference is made to a detailed description of research which was established to demonstrate the feasibility of developing a method for predicting the service life of plywood from its performance when subjected to accelerated-weathering treatments in the laboratory.

A correlation between the strength of plywood after successive cycles of boiling and drying and the strength after successive months of exposure to the weather has been demonstrated for phenolic resin adhesives of four strength values. This was done for both painted and unpainted Douglas-fir plywood.

A method is demonstrated for using this information to predict the service life of plywood made with new glue or with new variations of old glues.

The data are interpreted as affirming the evidence provided by Perkins (8) that "the higher the wood failure the greater the durability," and also affirming the worthwhileness of the methods of evaluating the bond quality of exterior plywood specified by CS45–55 and CSA0121–57.

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Compression of White-Pocket Veneer in Hot-Pressed Douglas-Fir Plywood[1]

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MUCH LOSS FROM DECAY IN old-growth Douglas-fir is caused by ed ring rot, *Fomes pini* (Thore) Lloyd. Decay caused by *Fomes pini* ften is called conk rot, white speck, r white pocket. Defective old-growth Douglas-fir will be a substantial part of the cut in Oregon for many years (3)[2] Large amounts of white pocket may be expected in large young-growth Douglas-fir by the time it is harvested.

Because of the large volume of peelable timber containing white pocket, and growing competition for veneer logs, many plywood plants have used, or are considering use of, white-pocket veneer in plywood manufacture. Utilization of white-pocket material should be based on sound technical knowledge of its properties and working characteristics.

Present grading rules of the Douglas Fir Plywood Association (D. F. P. A.) exclude all white pocket from structural plywood bearing the D.F.P.A. grade mark. General quality and strength properties of white-pocket plywood have been the object of considerable speculation. To obtain this information, the D.F.P.A. has sponsored cooperative research with the U. S. Forest Products Laboratory at Madison, Wis.

One property of white-pocket veneer not included in the cooperative study was degree of compression resulting when white-pocket veneers are made into plywood. Based on limited data from previous research at the Oregon Forest Research Center, compression appeared to be substantially greater in white-pocket veneer than in standard approved grades. Degree of compression would be important where plywood containing white-pocket veneer was to be sanded or converted to overlaid products having uniform thickness. A detailed study of compression characteristics of white-pocket veneer appeared to be a worthwhile addition to background data necessary for furthering utilization of Douglas-fir containing white pocket.

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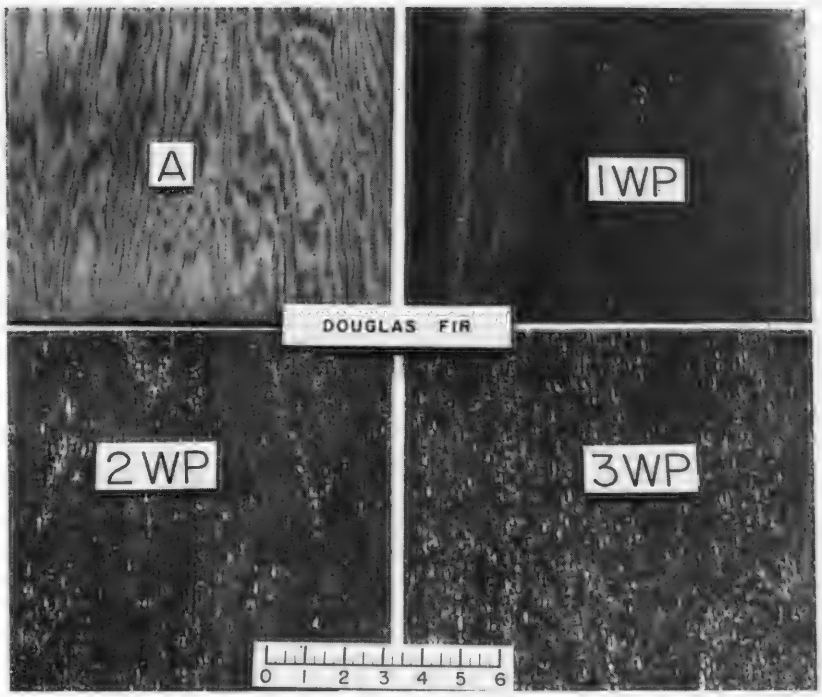


Fig. 1.—Representative squares indicating amount of white pocket permitted in each of four veneer grades.

Previous work has not stressed the degree of compression that occurs when white-pocket veneer is made into plywood. These data show not only the degree, but they also indicate possible methods of control and relief.

Previous Work and Related Studies

In 1945, Redfern and Fawthrop reported results of a study concerned with the inter-relationship of pressure and moisture content of veneer in Douglas-fir plywood hot-pressed with a liquid phenolic resin glue (12). Cheo has made a similar study where three different glues were used (phenolic film, liquid phenolic and soybean) (4).

A recent report by Curry (6) discussed the effect of veneer compression during pressing upon strength of plywood. Curry contended that, since compression increases plywood density, an increase in strength may be expected. He found that compression in plywood was confined to thin layers at the glue lines, and plywood actually consisted of layers of strong and weak wood separated by thin irregular bands of compressed wood.

A report by Macdonald discusses in detail major factors involved in compression of A-grade Douglas-fir veneer during pressing (10). Variables studied included time, temperature, and pressure. Curves showing relationship between percentage of compression and pressing time for various combinations of pressure and temperature are included in the report. In addition, a method for controlling amount of compression by use of a pressure-control device was outlined. The device was used successfully in producing plywood under conditions where total compression

[1] Presented at the FPRS Pacific Northwest Section Meeting, January 20, 1958; received by the Journal March 28, 1960.

[2] Numbers in parentheses refer to literature cited at the end of this report.

was limited to 7, 5, and 3 percent. Under similar pressing conditions without pressure control, compression was about 9 percent. Shear tests indicated satisfactory joints were obtained from plywood made with reduced pressure.

Measurement of compression occurring in plywood made with white-pocket veneers was a secondary objective of an unpublished report (9). The study gave valuable background information in techniques for measuring compression of plywood during hot-pressing.

Publications released by the Douglas-Fir Plywood Association have not included any studies on compression of plywood. Many of their reports do, however, include data on glue-line tests of plywood made from white-pocket veneer (1, 2, 5, 11, 13). Where an interior-type, hot-press resin was involved, plywood made from various grades of white-pocket veneer has shown good results in either the standard 10-cycle test or the dry shear test (1, 5, 7).

Objective

The present study was undertaken to obtain basic data on compression characteristics of plywood hot-pressed under standard conditions when made from Douglas-fir veneers containing various known amounts of white pocket. Once compression data were known, similar plywood could be manufactured under conditions whereby compression was limited by controlling the pressure cycle during hot-pressing. Quality of gluelines for both methods of plywood manufacture was checked by three different tests.

Experimental Procedure

Veneer Preparation

Dry ⅛-inch Douglas-fir veneer sheets[3] were clipped to 26 by 48 inches and sorted into 4 grades (A-grade, No. 1, 2, and 3 white pocket) by the mill's grading system for white pocket. A description of these grades follows:

No. 1 WP (white pocket)

a. Sound discolored material with small white specks appearing *occasionally;* no visible pockets present.
b. *Widely scattered* small and medium-sized white specks.
c. Numerous very small white specks; voids *filled* with whitish material.

No. 2 WP

a. White specks *generally* distributed, but with no heavy concentration; voids small and usually filled with whitish material.
b. Noticeable presence of white specks; small and medium-sized pockets *uniformly* scattered. No holes completely through veneer.
c. Pockets may be large, but confined to *narrow* streaks, with wide areas of sound wood between.

No. 3 WP

a. *Large* pockets, with or without white specks; pockets *few* in number and *widely* scattered.
b. *Concentrated* small and medium-sized pockets; holes may extend completely through veneer.
c. *Elongated* pockets, giving the appearance of several small pockets joined together; usually no white specks or very few present.

What This Research Means

Since this paper was presented, Commercial Standard 45–55, Douglas Fir Plywood, has been revised to permit use of controlled amounts of white-pocket veneer in interior plywood. Revisions were based upon extensive cooperative research between the Douglas Fir Plywood Association and the U. S. Forest Products Laboratory.

The basic data presented here for compession and recovery of hot-pressed Douglas-fir plywood made from sound and various grades of white-pocket veneer should be helpful to those mills utilizing white-pocket veneer. For instance, the amount of wood lost by compression was found to increase as the amount of white pocket increased. Knowledge of the compressibility of veneer will help to prevent the manufacture of hot-pressed panels with thicknesses below the minimum required by CS 45–55.

The data also demonstrate that compression of plywood, whether made of sound or white-pocket veneers, can be reduced without loss of bond quality by lowered pressure during hot pressing.

From the 26-by 48-inch sheets, 12-inch squares were cut. An attempt was made to obtain uniform distribution of white pocket over the full area of each 12-inch square, based on the range of white pocket allowed within a particular grade (Figure 1). Extremely rough-cut veneer or veneer containing defects such as knots or pitch pockets was discarded. The grading procedure was made more positive by having several members of the staff, who were familiar with the grading rules, check the squares of veneer.

For each of the 4 veneer grades, 100 squares were prepared, or enough to construct 20 five-ply panels. The 100 squares in a particular veneer grade were randomized by thorough mixing, and the veneer was sorted into plywood layups, each of which contained 5 sheets, with the grain direction of each ply at right angles to the adjacent sheet. To reduce any possible variation due to lathe checks the loose-cut sides of the face (back) and crossband plies were oriented facing each other. Each layup was code numbered in the upper right hand corner of the face sheet, and was stored in a room controlled to maintain EMC (equilibrium moisture content) conditions of 4 percent.

Trial Runs

Trial runs were made on a 12- by 12-inch laboratory hot press to determine number and placement of dial gages that would give a reliable estimate of compression during plywood hot-pressing.[4] Results indicated that dial gages would have to be mounted on all four corners of the press to average out differences in compression caused by localized variations present in white-pocket veneer (Figure 2).

Pressing Procedure

For each of the 4 veneer grades (A, No. 1, No. 2, and No. 3 WP) 10 plywood panels were pressed without pressure control and 10 were pressed with pressure control.

Initial Thickness: The 12- by 12-inch press was cold-flushed (57° to 60°F.) to minimize variation from expansion or contraction of the press platens. Ames dial gages mounted on the 4 corners of the press were set at 1.000 inch after closing the press and without pressure application.

Each plywood layup, without glue, was inserted in the press with its code number positioned uppermost in the right-rear corner. The press was closed, and without any applied pressure, the 4 dial gages were read. Average initial thickness of the 5 veneers was obtained by subtracting the average reading of the 4 dial gages from 1.000.

Pressing Without Pressure Control: The press was heated to 285° F., and the Ames dials were adjusted to read 1.000 inch. Crossbands of the individual layups were double spread with an interior-type extended phenolic resin.[5] Rate of spread of the adhesive to a thousand feet of double glue-line was 55 pounds for A-grade veneer and No. 1 WP, and 60 pounds

[3] Veneer was donated by the Edward Hines Lumber Co., Westfir, Oregon.

[4] The amount of compression in a small laboratory panel may be different than that found in a 4- by 8-foot panel from a commercial press. For example, the ratio of edge area to surface is much larger for a laboratory panel which may result in a greater degree of moisture loss during hot pressing.

[5] Glue was donated by Reichhold Chemicals, Inc., which also performed the shear tests discussed later.

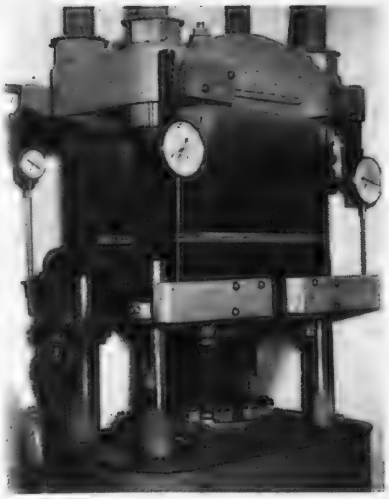


Fig. 2.—View of 12-inch-square hot press and dial gages for measuring compression.

for No. 2 and No. 3 WP. Special care was exercised in reassembling the veneers in the same orientation used in obtained initial thickness. After spreading, the veneers were given a closed assembly time of 5 minutes.

The assembly was inserted in the hot press with the code number of each panel again positioned uppermost in the right-rear corner. Pressure at 175 psi was applied for 7 minutes. Readings of the 4 Ames dial gages were recorded after ½, 1, 1-½, 2, 4-½ and 7 minutes' pressing time. After completion of the press cycle, the plywood panels were hot-stacked, allowed to cool, and placed in a controlled conditioning room at EMC conditions of 12 percent. Moisture content of the veneer at press time ranged from 3.5 to 4.7 percent.

Percentage of compression was determined by the following formula:

$$\frac{\text{total compression in 0.001 inch}}{\text{initial thickness}} \times 100$$

Pressing With Pressure Control: Full pressure during early stages of the press cycle was deemed necessary. After the glue had become partially polymerized pressure might be reduced without adverse effects upon quality of the bond. Therefore, rough curves depicting relationship of compression to pressing time were constructed, based on data collected during pressing at 175 psi without pressure control.

Decision was that 175 psi should be maintained for at least one-third of the pressing cycle. The rough curves indicated that A-grade, No. 1, No. 2, and No. 3 WP plywood reached about 5, 7, 9 and 12 percent compression, respectively, after 2-½ minutes in the press. An attempt was made to limit total gross compression to these percentages by use of the pressure-control device.

A complete description of the means of limiting compression by controlling pressure is given in the report by Macdonald (10). Included are schematic diagrams of the control system. Briefly, the device consists of limit-control instrumentation and remote by-pass valves located in the hydraulic pressure lines. Loaded platens of hydraulic presses can be controlled to stop automatically at any pre-selected amount of opening. When this point is reached, pressure progressively diminishes as a balance is maintained between resiliency of the veneers and pressure applied through the press ram. A patent covering this device has been issued to the State of Oregon.

Since average thickness of each plywood assembly was known, total allowable compression could be determined by multiplying desired percentage of compression by average thickness of the 5 veneers. The micrometer of the pressure-control mechanism was set to permit automatic control of pressure after reaching the allowable compression.

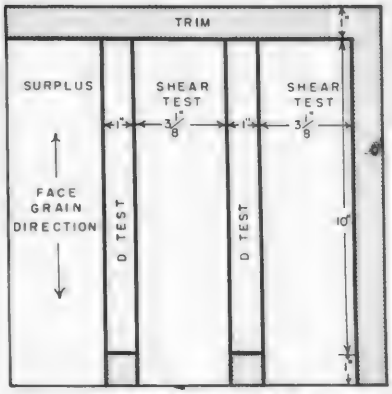
In pressing plywood with pressure control, all other variables, such as glue spread and assembly time, were exactly as outlined for plywood pressed without pressure control.

Recovery From Compression: A portion of the loss in thickness due to compression of plywood during hot-pressing is regained when the panels are subjected to reconditioning. Amount of recovery or springback may be important in the over-all consideration of white-pocket plywood. Usually, plywood is not sanded or subjected to further operations, such as overlaying, until several days after pressing. Therefore, final thickness of reconditioned plywood after recovery has occurred was an important factor to determine in this study.

After conditioning at EMC conditions of 12 percent for 2 weeks, the average thickness of each plywood panel was determined in accordance with the procedure outlined for measuring initial thickness. The panels were returned to the conditioning room for 2 additional weeks, and thickness was again measured. After calculating the final compression, amount of springback was determined.

Testing Procedure

Specimens for checking quality of glue bond were prepared from the 12-inch squares of plywood according to the cutting plan shown in Figure 3. One inch was trimmed from each of 2 adjacent edges, and strips 3-⅛ by 11 inches and 1 by 11 inches, alternately, were ripped until 2 of each



CUTTING PLAN FOR PLYWOOD TESTS

Fig. 3.—Cutting plan for plywood tests.

type were obtained from the square. Direction of the face grain was oriented parallel to the long dimension of the strips.

The larger strips, 3-⅛ by 11 inches, were sent to the Cooperators laboratory in Seattle, Washington, where standard shear specimens 1 by 3-⅛ inches were prepared. To nullify any possible effect from orientation of the lathe checks, the kerf was reversed on one of the 2 strips from each plywood panel.

Ten shear specimens from each plywood panel were subjected to the standard 2-cycle boil test, which consisted of boiling 4 hours, drying 16 hours at 145° ± 5° F., and boiling 4 hours. While still wet, the specimens were broken in a standard shear-testing machine for plywood. Percentage of wood failure was estimated after the broken pieces dried.

Another group of 10 shear specimens from each plywood panel was soaked in water at room temperature for 48 hours and then sheared wet. Percentage of wood failure was estimated in the same manner prescribed for the 2-cycle boil specimens. In both tests, half the specimens were chosen to pull the lathe checks closed, and the other half open. Both types of shear tests were performed by the cooperator[5].

The 1- by 11-inch strips were trimmed to 10 inches in length, and one strip for each plywood panel was subjected to a delamination test, which consisted of 15 cycles of alternate soaking and drying. A complete description of the test has been outlined by Haigh (8), including its advantages as a laboratory tool when compared to the standard 10-cycle test for interior-type plywood. One cycle of the modified test (named the D test by Haigh) consists of soaking 16 hours in water at room temperature (65–70° F.) followed by drying 8 hours in a forced-draft oven at 150° F. Amount of delamination was deter-

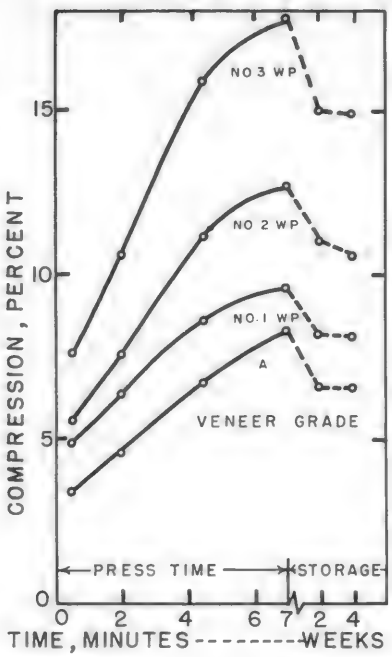


Fig. 4.—Compression without pressure control.

mined after the tenth and fifteenth cycles by measuring the number of inches of delamination at least 0.25 inch in depth. The D test was made at the Research Center.

Results and Discussion

Compression, recovery from compression, and strength of glue bonds were important items measured.

Compression During Hot-Pressing

The compression characteristics for all 4 veneer grades during the hot-pressing cycle of 7 minutes at 285° F. and 175 psi are shown in Figure 4. For a given grade of veneer, increase in compression with time was almost linear between ½ and 4-½ minutes. During the remainder of the pressing time, a gradual reduction in rate of compression took place. Average compression after 7 minutes in the press was 8.3, 9.6, 12.7 and 17.8 percent for A grade, No. 1, No. 2 and No. 3 WP veneer, respectively (Table 1). No. 3 WP veneers compressed more than twice the amount found for A grade. However, compression of No. 1 WP veneer was only slightly greater than that of A grade.

Range in total compression for the 10 plywood panels within a particular veneer grade showed a wide variation. For both A grade and No. 1 WP, there was a difference of about 4.5 percent in total compression between the panels with maximum and minimum compression. This difference increased to 7 percent for No. 3 WP (Table 1).

The family of curves depicting compression of the 4 grades of veneer when pressure control was utilized are quite different in slope when compared to the series pressed with a uniform pressure of 175 psi (Figures 4, 5). Decreasing pressure resulted in a slightly curvilinear shape to the curves throughout the pressing period with rate of compression decreasing as pressing time increased.

An attempt was made to limit total compression during hot pressing to 5, 7, 9 and 12 percent for A grade, No. 1, No. 2 and No. 3 WP, respectively. The compression-control device functioned satisfactorily, and average compressions at the end of the 7-minute hot-pressing period were 5.6, 7.2, 9.4 and 13.0 percent (Table 1).

Another benefit gained from use of compression control, aside from reduction in total compression during pressing, was narrowing of the range between the panels with maximum and minimum compression. For the 10 panels made from A-grade veneer, the range was 1 percent; No. 3 WP veneer had a variation of only 1.9 percent (Table 1).

Effect on compression of pressing No. 2 WP veneer with and without pressure control is shown in Figure 6. If curves for A grade, No. 1, and 3 WP were included, the general relationship between plywood pressed with and without pressure control would be similar to No. 2 WP. In plywood pressed with pressure control, lower amounts of compression occurred during almost the entire 7-minute pressing period. Theoretically, compression of plywood by both pressing methods should have been of

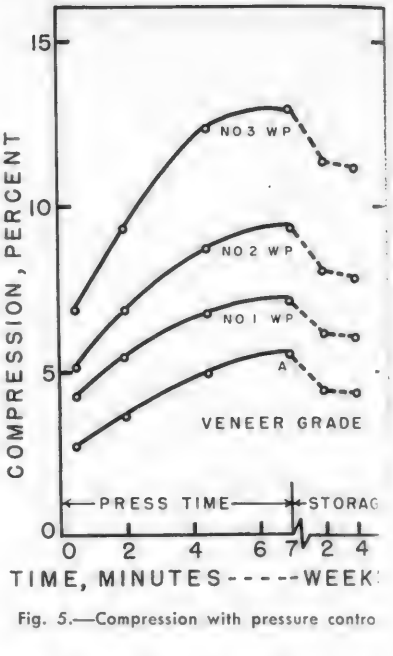


Fig. 5.—Compression with pressure contro

the same magnitude during the fir 2-½ minutes of pressing, becau pressure was supposed to be consta at 175 psi. Due to the range of co pressibility normally encountered veneer (see Table 1), however, a fe plywood panels reached total allow able thickness before 2-½ minut elapsed in the press. Pressure w reduced automatically and, in tur compression was lowered. Premature reduction in pressure also affected th typical press-cycle pressure curves Figure 7.

Mechanical capabilities of the con trol device would have permitted lim iting compression to much lower amounts than chosen for any of th veneer grades. Full pressure of 17 psi would have been maintained for a much shorter period after closing th press, however, and the curves for pressure reduction would have been lowered considerably compared to th curves in Figure 7. Effects of su lowered pressures during initial stag of the press cycle upon quality of t glue bonds are not known.

Table 1.—COMPRESSION WITH OR WITHOUT CONTROL

Veneer grade	Compression* after pressing			
	No pressure control		With pressure control	
	Average %	Range %	Average %	Range %
A	8.3	6.5-10.9	5.6	5.1- 6.1
1 WP	9.6	8.1-12.4	7.2	6.6- 8.0
2 WP	12.7	10.8-15.9	9.4	8.9-10.0
3 WP	17.8	15.1-22.0	13.0	11.7-13.6

*Based on 10 panels for each veneer grade.

Table 2.—RECOVERY FROM COMPRESSION WITH OR WITHOUT CONTROL

Veneer grade	Compression			
	Average after pressing %*	Conditioned 4 weeks %**	Recovery %	%
No pressure control				
A	8.3	6.6	1.7	20.5
1 WP	9.6	8.1	1.5	15.6
2 WP	12.7	10.6	2.1	16.5
3 WP	17.8	14.9	2.9	16.3
With pressure control				
A	5.6	4.4	1.2	21.4
1 WP	7.2	6.1	1.1	15.3
2 WP	9.4	7.9	1.5	16.0
3 WP	13.0	11.2	1.8	13.8

*Based on initial thickness of unpressed veneers.
**Based on amount of compression caused by 7 minutes' hot-pressing.

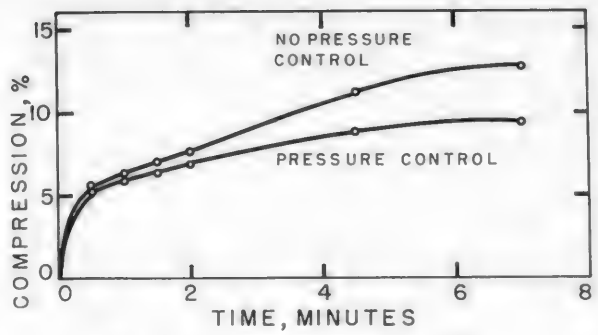


Fig. 6.—Compression of No. 2 WP veneer.

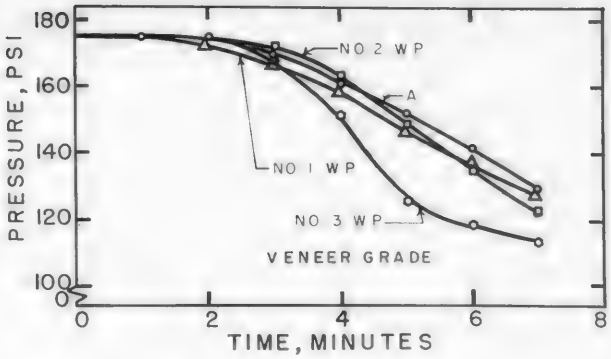


Fig. 7.—Press cycle pressure of plywood with pressure control.

Recovery from Compression

Degree of recovery from compression when the hot-pressed plywood is reconditioned is shown in Figures 4 and 5. After 2 weeks' exposure in an atmosphere having EMC conditions of 12 percent, most springback had occurred. Little additional recovery developed during 2 more weeks of conditioning.

Table 2 presents recovery from compression for plywood pressed with and without pressure control. Percentage of recovery has been computed by two different bases. When based upon initial thickness of unpressed veneers, recovery was greatest in plywood containing the heavier concentrations of white pocket. If amount of compression after 7 minutes of hot-pressing was the base for computing percentage of recovery, A-grade veneer exhibited the greatest recovery. All three grades of white-pocket plywood had recovery quite similar in magnitude. These recovery relationships were true for plywood pressed either with or without pressure control.

Glue-Bond Tests

Three different tests were performed on the plywood in an effort to determine if reduced pressure during pressing was detrimental to quality of glue bonds. Two tests were of the shear type, and they commonly are called the 2-cycle-boil and 48-hour-soak tests. The third test was a delamination type based on alternately soaking and drying the plywood.

Shear tests. In evaluating extended phenolic resin glues, a standard 2-cycle-boil test is often performed. Experience has shown that a good extended phenolic resin glue will give wood failures ranging from 50 to 80 percent. The 48-hour-soak test is helpful in determining degree of cure with phenolic resin glues.

In both the 2-cycle-boil and 48-hour-soak tests, breaking loads of shear specimens decreased steadily as degree of white pocket in the plywood increased (Figure 8, Tables 3, 4). This relationship has been confirmed by other investigators. Within each type of shear test, there appeared to be no great differences in breaking load of plywood made from similiar veneers and pressed with and without pressure control.

One result worthy of note may be seen by comparing the two types of shear tests in Figure 8. The general trends within each type of test were almost identical, with the 48-hour-soak test shifted upward due to higher breaking loads. Results indicated relative severity of the different test procedures upon the glue bonds.

Results for percentage of wood failure by the two test methods may be found in Figure 9 and Tables 3 and 4. Note that percentage of wood failure probably was not a reliable criterion when plywood contained white pocket. Amount of wood failure will be affected by reduced strength of the wood. Furthermore, accuracy of estimating percentage of wood failure in material containing numerous pockets or void spaces is questionable. Therefore, only general trends in the results will be discussed.

Similarly to breaking load, a distinctive trend developed when percentage of wood failure was plotted over grade of veneer (Figure 9). This time, however, pressure during pressing, rather than test method, appeared to be the critical variable. In general, plywood made with pressure control developed greater percentage of wood failure when compared to plywood made with no pressure control. A major exception to this relationship occurred in plywood with No. 2 WP, where percentage of wood failure of plywood pressed without pressure control was higher. A-grade plywood pressed without pressure control apparently developed lower percentage wood failure than might be expected.

D test: In evaluating interior-type plywood, delamination resulting from alternately soaking and drying test specimens usually is the basis for determining quality of the glue line. The size and grain orientation of the D-test specimen results in rapid saturation during soaking and complete removal of water during drying. Severe stresses are set up within the glue lines, and these are conducive to accelerated delamination (8).

Percentages of delamination in plywood produced with and without pressure control are listed in Table 5. Little delamination developed during the first 10 cycles; the maximum was 1.3 percent for A-grade veneer pressed without control. Remainder of the plywood had 1 percent or less delamination.

Table 3.—TWO-CYCLE-BOIL TEST

Veneer grade	No pressure control		With pressure control	
	Breaking load* Psi	Wood failure* %	Breaking load* Psi	Wood failure* %
[illegible]	174	48	198	90
WP [illegible]	170	53	156	64
WP [illegible]	125	90	134	78
WP [illegible]	100	51	93	59

*Based on 10 specimens from each of 10 plywood panels.

Table 4.—FORTY-EIGHT-HOUR-SOAK TEST

Veneer grade	No pressure control		With pressure control	
	Breaking load* Psi	Wood failure* %	Breaking load* Psi	Wood failure* %
A	220	62	231	94
1 WP	207	53	182	74
2 WP	147	93	154	84
3 WP	117	65	111	75

*Based on 10 specimens from each of 10 plywood panels.

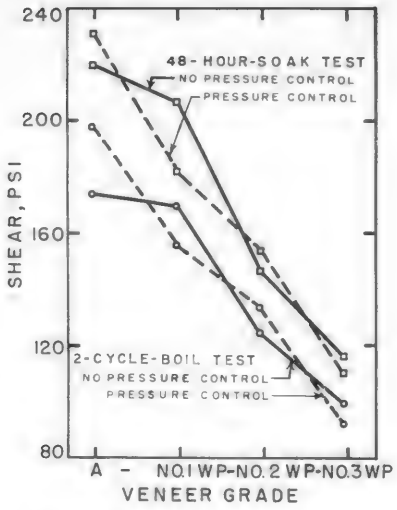


Fig. 8.—Shear strength by two methods.

Five additional cycles of soaking and drying did little to change amount of delamination. An exception was A-grade plywood pressed without control, where delamination increased from 1.3 to 6.0 percent. The glue bond of this plywood previously was suspected to be below average, based on percentage of wood failure in the shear tests. In general, the remainder of the plywood, including all grades of white pocket, showed excellent resistance to delamination.

As the D-test cycles progressed, development of checking in the crossbands was much more severe in A-grade plywood than in low grades of white-pocket plywood (Figure 10). Lack of check development in white-pocket plywood may be attributed to its "built in" system of checks in the form of numerous white pockets and void spaces.

The good resistance to delamination shown by white-pocket plywood also may be due to existence of the white pockets. Examination of ends of the D-test specimens (Figure 11), made evident that more severe stresses were established in the face-crossband glue lines of A-grade plywood than in No. 3 WP plywood. Curling of face plies of A-grade plywood often resulted in initiation of delamination. In many instances, a break developed along the face-crossband glue line, but this break usually was less than 0.25 inch in depth and, therefore, was not classified as delamination.

Conclusions

Based on data developed during manufacture and glue-bond testing of plywood containing white-pocket veneers, the following conclusions may be drawn:

1. When standard hot-pressing schedules were used, degree of compression in white-pocket veneers increased as amount of white pocket increased. Compared to A-grade veneer, compression of No. 1 WP increased only slightly, while compression of No. 3 WP was more than doubled.
2. Total compression of plywood made from any type veneer can be reduced through use of pr sure control during hot-pressin
3. Compression developed duri hot-pressing may be relieve partially by reconditioning t plywood. Majority of recove took place within 2 weeks aft pressing.
4. Based on standard glue-l shear tests, breaking strength plywood made with white-poc veneer decreased as amount white pocket increased.
5. Percentage of wood fail probably is not a reliable in cator of glue-bond quality wh plywood contains white pocke

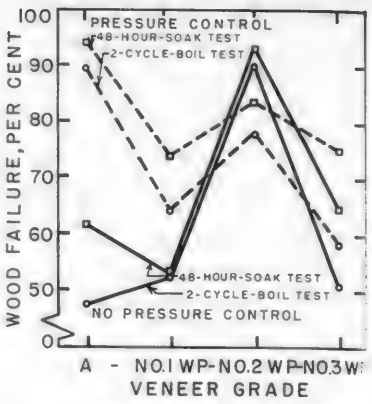


Fig. 9.—Wood failure by two methods.

Table 5.—DELAMINATION BY D TEST

Veneer grade	Delamination* after cycles indicated			
	No pressure control		With pressure control	
	10 cycles	15 cycles	10 cycles	15 cycles
	%	%	%	%
A	1.3	6.0	0.1	0.2
1 WP	0.3	0.8	.1	0.2
2 WP	0.0	0.0	.0	0.2
3 WP	1.0	1.6	.5	1.0

*Based on average of 10 specimens for each veneer grade.

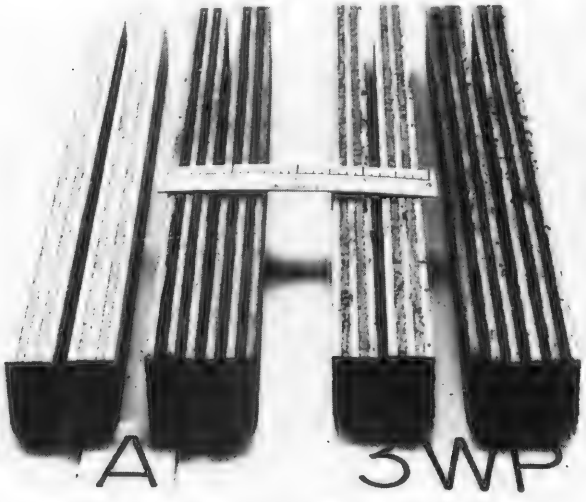


Fig. 10.—Checks developing during the D-test were more prevalent in A-grade veneer than in No. 3 WP.

Fig. 11.—Stresses resulting from D-test were more severe in A-grade veneer than in white-pocket veneer.

6. All grades of white-pocket plywood, pressed with or without pressure control, showed excellent resistance to delamination when subjected to a test procedure considered standard for interior plywood.
7. The possibility exists that acceptable plywood bonds could be obtained with pressures reduced gradually immediately after full initial pressure is applied.

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Quality-Controlled Log Bucking

PRODUCES HIGH-GRADE LOGS AND TOP LUMBER $$$

E. W. FOBES

Forest Products Laboratory,[2] Forest Service
U. S. Department of Agriculture

THE PERCENTAGE OF HIGH-grade logs obtained in timber harvesting operations can be influenced considerably by the knowledge, judgment, and care used in bucking tree lengths into logs. A good working knowledge of a log quality standard that is based on the quality or value yield of the end product is necessary. The quality standards used for timber are designated log grades.

Standard log grades have been developed by the Forest Products Laboratory for eastern hardwood logs. Application of these grades has proved that the quality yield of lumber from a group of logs can be predicted within reasonable limits of accuracy.

The Author: Eugene Fobes was for many years a forester and technologist at the USFPL, with an intervening period with the Foreign Operations Administration assigned to U.S. Operations in Liberia. He resigned from the Laboratory early in 1960 and is now Vice-President of Liberian Timber Industries Corp., Monrovia, Liberia.

To determine the applicability of these log grades to western hardwoods, a study was made on California black oak. Lumber grade yields proved that standard log grades could be used for determining timber quality. Analyses of the logs used in the study, however, indicate improved log grade yield could have been obtained if the logs had originally been bucked according to log grade. This report presents an analysis of the logs in this study.

Origin of Logs

Most of the logs were produced by loggers accustomed to softwood timber. Both single- and multiple-length logs were delivered to the mill. The multiple-length logs required rebucking, and presented some opportunity to improve the grade of the resulting logs. The other logs used in the study were produced from trees marked for bucking by the study crew, which was familiar with hardwoods.

The study logs, therefore, are divided into three groups for analysis. Group one contains the short logs that did not require bucking. Group two contains the logs bucked from long logs, and group three contains the logs from trees marked by the study crew.

Log Lengths

Logs and tree lengths available at the start of the study are listed in Table 1. Lengths of logs are listed to the next lowest foot: that is, logs 10 feet to 10 feet-11 inches are listed as 10 feet. Trim allowance, which on these logs varied considerably, also lends itself to quality control on logging operations, and should not vary more than 2 or 3 inches from the set standard. Normally, the maximum

[1] A contributed paper received by the Journal February 12, 1960.

[2] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

Fig. 1.—California black oak tree with characteristic crook.

Fig. 2.—California black oak log with "Pistol butt."

length for single hardwood lumber logs is 16 feet. Logs longer than this are considered to be multiple-length lumber logs to be rebucked at the mill. Trim-allowance specification on well-controlled operations is usually 3 to 4 inches for single-length logs.

The percentage of logs in each trim-allowance class is shown in Table 2.

Only 17 percent of the 16 foot and under logs cut by the regular logging crew had a trim allowance of 3 to 4 inches. Thirty-nine percent of the logs cut as directed by the study crew were in this class. Considering a trim allowance of 2 to 6 inches as an acceptable range of variation, there were 48 to 79 percent, respectively, in these groups that met this standard. A percentage of longer and shorter trim is inevitable because of forks and large limbs. The objective of quality control and good utilization is to keep this percentage as low as possible.

Logs 17 to 23 feet in length are considered double-length logs. Trim allowance, therefore, should be 6 to 8 inches. Logs 24 to 36 feet in length are either double- or triple-length logs, with corresponding trim allowance.

Rebucking

To reduce excessive sweeps and crooks, it was necessary to rebuck a few of the logs that were less than 16 feet long. Rebucking of three short logs raised the grade of one section on each. The grade of three additional short logs would have been higher had they been correctly bucked in the woods. The 9 logs representing 6 percent of the logs 16 feet long or under would not have been rebucked had they been correctly bucked in the woods. There is little doubt that better log grade recovery would have resulted if these logs had been left in multiple or tree lengths.

Know-how and good judgment in bucking tree lengths into logs have a strong influence on the value of the end product. Here, controlled bucking of western hardwoods increased the overall value of the lumber yield by $15 per 1,000 board feet.

The number of logs in each length class after rebucking is shown in Table 3.

On most hardwood lumber operations, there should be no logs less than 8 feet long. California black oak, however, is characteristically crooked (Fig. 1). Short crooks in the butt logs are descriptively termed "pistol butt" since they resemble the handle on a revolver (Fig. 2). Logs cut 8 or more feet long result in excessive sweep (Fig. 3) that lowers the log grade and lumber recovery volume, as well as lumber grade. Best utilization of crooked logs can therefore be attained by cutting short bolts 4 to 7 feet long and processing them on a bolter or short-log saw (Fig. 4). Some of the 5, 6, and 7 foot lengths shown in Table 3 were cut for this reason.

An example of this short-log bucking is a log 27 feet long bucked into two logs 10 feet 3 inches long, and one 6 feet 4 inches. The 6-foot log still had 5 inches of sweep and was Grade 4. The two logs 10 feet long were Grade 3. The original log could have been bucked into one 10-foot and two 8-foot logs, of which 8 feet would have graded No. 4. The choice was therefore between producing 18 or 20 feet of No. 3 logs.

Lack of familiarity with hardwood log grades by the pine logging crew also resulted in some short logs. An example of this was a log cut 33 feet 6 inches long. The first log bucked was 10 feet, Grade 3. Because of f[illegible] defects, the next- 8-foot section was Grade 4. The remaining section had sweep and was Grade 4, but w[illegible]

Fig. 3.—Log with excessive sweep.

Table 1.—NUMBER OF LOGS RECEIVED, BY LENGTHS

Group 1		Group 2		Group 3[1]	
Length Ft.	No.	Length Ft.	No.	Length Ft.	No.
6	1	13	1	30	1
7	0	14	5	32	1
8	29	15	1	37	2
9	24	16	2	41	1
10	23	17	6	43	1
11	15	18	8	44	1
12	20	19	10	45	1
13	8	20	3	47	1
14	11	21	8	50	1
15	8	22	1	52	1
16	7	23	7	56	1
17	4	24	10	57	1
		25	7	60	1
		26	10	63	1
		27	6	69	1
		28	11	90	1
		29	10	91	1
		30	12	95	1
		31	4	98	1
		32	4		
		33	12		
		34	12		
		36	1		
Total	150		151		20

[1]Tree lengths.

bucked to produce an 8-foot Grade 3 log. This left 7 feet that had to be Grade 4 because of length. If this log had been 1 foot longer, it would have been a Grade 3 log. There was no double heart or other apparent reason for cutting the tree at this point. Also, because of length limitation, the trim allowance on these logs was less than it should have been. (Fig. 5).

The number of logs less than 8 feet long can be reduced by eliminating bucking errors, and accepting a reduction in volume and grade recovery.

Log Grades

The grades of logs obtained are listed in Table 4. Grade 4 is not a standard grade, but represents logs that do not meet the minimum Grade 3 specifications. It could be erroneously assumed from the percentage columns in Table 4 that there was a difference in the quality of the timber from which the logs were cut. Variation in the percentage of Grade 3 or 4 in each group is small, however, and less than two standard deviations.

The loggers' knowledge of hardwoods in general and hardwood log grades in particular significantly affects the percentage of Grade 1 logs obtained. Logs in Groups 1 and 2 were cut by loggers not familiar with hardwoods, whereas Group 3 logs were cut under the direction of persons familiar with hardwoods. It was therefore logical to determine whether the difference in percentage recovery of Grade 1 logs was due to differences in timber quality or log bucking. Log diagrams were therefore carefully analyzed. A number of logs obviously could have been bucked differently. In Group 1, for example, there were two logs 17 feet long that were Grade 2. Had these logs been cut 12 feet long, they would have been Grade 1. The remaining 5 feet should have been on the next log. There were several similar logs in the group.

An example of logs in Group 2 was a log 21 feet long that was bucked into a 12-foot Grade 2 log, and a 9-foot Grade 3 log. Sixteen feet of this log was Grade 2 quality. Another log 28 feet long was bucked into one Grade 2 and two Grade 3 logs. It could have been bucked into just two logs (Grade 2 and 3) thus reducing Grade 3 by one log. One log 25 feet long was bucked into one Grade 1 and a Grade 2 log, with 5 feet that and one Grade 3 log. It could have been bucked into a Grade 1 log in the tree.

Re-evaluation of these logs is shown in Table 5 in addition to these logs, there were several that might have been one grade higher if they had been 1 or 2 feet longer. Since the trees and logs were not numbered in the woods, the quality of the sections cut off could not be determined and no changes could be made. It is very probable, however, that a few of these logs could have been up-graded if they had been bucked for quality. The percentage of Grade 1 logs in Groups 1 and 2, shown in Table 5, can therefore be considered conservative.

Since the logs in Groups 1 and 2 came from the same trees, the data from Tables 4 and 5 have been combined and are shown in Table 6.

Statistical comparison of the corrected groups indicates the variation of log grade distribution is within the normal range for samples of this size. This criteria therefore indicates there is no significant difference in the quality of timber between the groups. It can therefore be concluded that the primary difference in log grade recovery between the uncorrectd groups was due to the difference in bucking techniques.

Lumber Volume Recovery

Log diameter and length are important items in hardwood log grade specifications. Larger minimum log sizes are specified in Grades 1 and 2 than in Grade 3. The percentage of lumber obtained from Grade 1 or 2 logs is therefore greater than the percentage of logs in the grade. Table 7

Fig. 4.—Log with short crooks, which can be fully utilized by use of a bolter saw.

Table 2.—PERCENTAGE OF LOGS, BY TRIM ALLOWANCE

Group	Log length Ft.	Trim allowance, inches											
		0	1	2	3	4	5	6	7	8	9	10	11
		%	%	%	%	%	%	%	%	%	%	%	%
1 & 2	0-16	8	5	10	10	7	6	15	6	14	7	9	3
1 & 2	17-23	6	7	4	9	15	4	13	7	9	9	13	4
1 & 2	24-36	13	7	16	8	5	4	8	7	10	9	8	5
	0-16	3	6	13	19	20	12	15	4	4	1	2	1

Table 3.—NUMBER OF LOGS BY LENGTHS AFTER REBUCKING

Length Ft.	Group 1 No.	Group 1 %	Group 2 No.	Group 2 %	Group 3 No.	Group 3 %
5	0	0	2	1	1	1
6	1	1	7	2	1	1
7	0	0	15	4	2	2
8	29	20	79	22	23	23
9	24	16	32	9	3	3
10	23	15	87	24	19	19
11	15	10	19	5	2	2
12	20	13	49	13	26	26
13	8	5	12	3	1	1
14	11	7	28	8	7	7
15	8	5	5	1	1	1
16	7	5	24	7	14	14
17	4	3	3	1	0	0
Total	150	100	362	100	100	100

Table 4.—LOG GRADES OBTAINED

Log Grade	Group 1 No.	Group 1 %	Group 2 No.	Group 2 %	Group 3 No.	Group 3 %
1	5	3	15	4	13	13
2	41	28	87	24	12	12
3	60	40	148	41	43	43
4	44	29	112	31	32	32
Total	150	100	362	100	100	100

Fig. 5.—Groups 1 and 2 California black oak logs.

shows that the percentage of lumber recovered from Grade 1 logs is 2¼ times the percentage of logs for both groups. On this percentage basis, there is no significant difference in size distribution within the two stands of timber from which these logs were harvested. It is therefore evident that poor bucking practices are responsible for a considerable reduction in lumber volume from high-grade logs.

Lumber Recovery Value

Log value was determined by application of oak prices (1957) to the lumber volumes, by grade, obtained from each log. The total value and mill tally volume of each log was used to determine the average per 1,000 board feet. These data were then used in calculating the values shown in Table 8.

There was no significant group effect on mean values of either Grade 2, 3, or 4 logs. Difference in the mean value of Grade 1 logs, however, appears large but is less than 2 standard deviations. Variation in log size might account for this difference. Examination of the data, however, indicates the average log diameters were 21.55 and 20.85 inches for the two groups. Average log lengths were 12.85 and 12.69 feet. Neither of these variations is significant.

Total value and volume of lumber in each group of logs were used to calculate the average lumber values, which were $100.68 and $115.54. The major reason for this difference is the percentage and value of Grade 1 logs. As previously pointed out, the percentage of Grade 1 logs is significantly influenced by the division or bucking of tree lengths into logs.

Conclusions

The quality of the timber used in this study from the two separated areas of the forest is not significantly different. Major differences in recovery values are due to production methods. Log bucking instructions and how log lengths are cut from tree lengths have a significant effect on the percentage of Grade 1 logs obtained. Since log grading specifications limit the minimum size of Grade 1 logs, the effect on volume of lumber is greater than the effect on the percentage of logs within the grade. This means that a quality control program that increases the percentage of Grade 1 logs will result in a higher percentage increase in volume from Grade 1 logs.

Although the number of Grade 1 logs analyzed in this report makes it too small a sample to provide conclusive evidence, there is a strong indication that the mean value for the grade is also influenced by log bucking procedures. This is indicated by the fact that the timber is not significantly different, yet the spread between $127 and $156 (Table 8) is greater than the expected variation of the mean.

Similar effects decrease in significance as log grade decreases in quality and restrictive specifications. It is therefore very important in harvesting hardwood timber to obtain the maximum percentage of Grade 1 logs. It is probable that quality control standards based on the percentage of Grade 1 logs can be set up from the cruising records for specific timber stands. Quality control of bucking can thereby be maintained during harvesting. In this particular study, the overall average difference in value of $15 per 1,000 board feet is sufficient to justify a quality control program.

Table 5.—POSSIBLE LOG GRADES IF TREES HAD BEEN BUCKED FOR QUALITY

Log Grade	Group 1 No.	Group 1 %	Group 2 No.	Group 2 %	Group 3 No.	Group 3 %
1	17	11	27	8	14	14
2	37	24	97	28	13	13
3	57	38	129	38	41	42
4	40	27	91	26	30	31
Total	151	100	344	100	98	100

Table 6.—LOGS GROUPED ACCORDING TO SOURCE OF TIMBER

Log grade	Groups 1 and 2 as bucked No.	Groups 1 and 2 as bucked %	Groups 1 and 2 corrected No.	Groups 1 and 2 corrected %	Group 3 corrected No.	Group 3 corrected %
1	20	4	44	9	14	14
2	128	25	134	27	14	14
3	208	41	186	38	40	41
4	156	30	131	26	30	31
Total	512	100	495	100	98	100

Table 7.—LUMBER YIELD FROM LOG GRADES

Log grade	Groups 1 and 2 Bd. ft.	Groups 1 and 2 %	Group 3 Bd. ft.	Group 3 %
1	4,553	9	3,187	2
2	17,516	35	2,014	1
3	18,813	38	3,572	3
4	9,281	18	2,064	1
Total	50,163	100	10,837	10

Table 8.—VALUE OF LUMBER PER 1,000 BOARD FEET

Log grade	Groups 1 and 2 Mean value Dollars	Groups 1 and 2 Standard deviation Dollars	Groups 1 and 2 No. of logs	Group 3 Mean value Dollars	Group 3 Standard deviation Dollars	Group 3 No. of logs
1	127.29	26.09	20	156.01	19.16	1
2	104.49	23.77	128	109.08	24.81	1
3	84.73	18.42	208	88.57	23.44	4
4	69.43	18.22	156	68.61	23.85	3

Pipeline Transport of Pulpwood Chips[1]

D. R. ELLIOTT

Pulp and Paper Research Institute of Canada

This project takes the hydraulic transport of wood chips out of the "skyhook category" and proves its feasibility. Conclusions were (1) Chip deterioration is no problem, (2) Mixtures up to 30% solid wood can be handled, (3) Friction losses and power requirements are close to those for water alone.

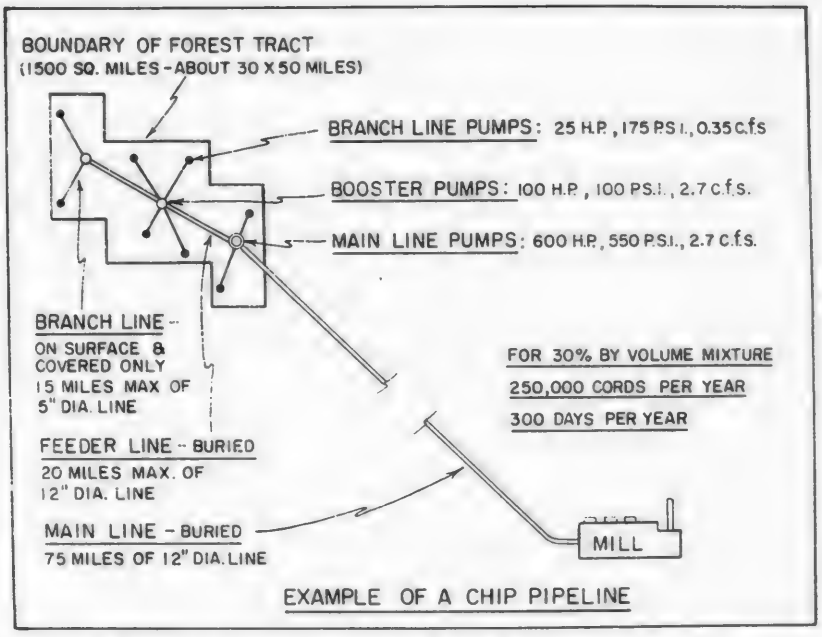
BOUNDARY OF FOREST TRACT
(1500 SQ. MILES - ABOUT 30 X 50 MILES)
BRANCH LINE PUMPS: 25 H.P., 175 P.S.I., 0.35 C.f.s
BOOSTER PUMPS: 100 H.P., 100 P.S.I., 2.7 C.f.s.
MAIN LINE PUMPS: 600 H.P., 550 P.S.I., 2.7 C.f.s.
BRANCH LINE -
ON SURFACE & COVERED ONLY
15 MILES MAX OF 5" DIA. LINE
FOR 30% BY VOLUME MIXTURE
250,000 CORDS PER YEAR
300 DAYS PER YEAR
FEEDER LINE - BURIED
20 MILES MAX. OF 12" DIA. LINE
MAIN LINE - BURIED
75 MILES OF 12" DIA. LINE
MILL
EXAMPLE OF A CHIP PIPELINE

Fig. 2.—Layout of pipeline system capable of collecting and transporting 5 million cords of pulpwood chips over a 20-year period.

PIPELINES HAVE BEEN USED TO carry liquids for centuries. Excavations in Libya have uncovered evidence that the ancient Egyptians coupled together sections of hollowed-out trees to carry water. Elm was used for this same purpose in London, England about the time of Charles I. Today, transcontinental networks of steel pipe carry huge quantities of materials such as petroleum products and natural gas over thousands of miles.

The hydraulic transport of solids in pipes over long distances is very recent. United States patent records around 1890 proposed such transport of coal, but it was not until 1958 that the vision became reality with the opening of the 108-mile coal pipeline between Cadiz and Eastlake in Ohio. Of more direct interest to the transport of wood chips is the 72-mile, 6-inch diameter pipeline that carries 700 tons of gilsonite each day of the year over the Brookcliffe mountains, from mines in Utah to a refinery in Colorado. Gilsonite, like wood, is non-corrosive and has a specific gravity very close to that of water. The company is very pleased with the satisfactory operation of the line over the last 3 years and can show that the investment was a good one, even though the capital required by alternative methods of transport would have been much less.

Interest in the possibility of transporting wood by pipeline has been building up for some time, but at first the idea was thought to be in the sky-hook category. With greater mechanization in the woods, managers have been thinking more and more of production line methods. Furthermore, the trend towards continuous chemical pulping, which has become so much more attractive as a result of recent researches, and the successful manufacture of high-quality mechanical pulp from wood chips, has made it desirable to deliver pulpwood to the mill in the form of chips, ready for pulping.

Hydraulic Transport of Pulpwood Chips

In 1958, after a small laboratory experiment the year before, the Pulp and Paper Research Institute enlisted the assistance of Foundation of Canada Engineering Corporation, Aluminum Company of Canada, Canadian Ingersoll-Rand Company, Greey Mixing Equipment Ltd., Victaulic Company of Canada, Peacock Brothers and Canadian International Paper Company in a pilot plant study of the hydraulic transport of wood chips in pipelines. The companies furnished equipment and constructed a complete pilot plant with one-tenth of a mile of 8-inch diameter aluminum pipe. The Institute provided instrumentation, operated the system, and carried out all tests and analyses.

Figure 1 shows the main elements of the pilot plant. The mixing tank on the left is equipped with a side-entering mixer (not shown). The large pipe connected on the right of the mixing tank near the bottom is the suction line to the pump. The pump at the extreme right discharges vertically for about 8 feet, around two 45-degree standard elbows and into the horizontal aluminum pipe shown in the upper right. Most of the line is in the crawl space under the building and contains 90- and 180-degree bends made from standard short-radius 45-degree elbows. The pipeline discharge is at ceiling level above the mixing tank, and it can be directed to fill or to bypass a measuring tank (not shown)

The Author: An honor graduate of the University of Toronto, David Elliott joined the Institute in 1957. He is now Senior Mechanical Engineer in the Woodlands Research Department.

[1] Presented at Session XIII, Logging, FPRS 14th Annual Meeting June 8, 1960 in Montreal, Canada.

COOKING DATA AND PHYSICAL TEST RESULTS (15 % BY VOLUME MIXTURE) EQUIPMENT USED – MIXER, PUMP, AND 528 FT. OF PIPE			
SULPHITE COOKS SODA BASE	COMPARED AT 300 FREENESS		
	CONTROL	SINGLE PASS	150 PASSES
YIELD – %	50	50	50
BURST FACTOR	81	76	64
TEAR FACTOR	71	64	59
BREAKING LENGTH – M.	12,800	12,400	11,700
STRETCH – %	3.2	3.0	3.1
BULK – cc./gram	1.22	1.20	1.18
DOUBLE FOLDS – M.I.T.	2,200	1,965	1,630

CHIP CLASSIFICATION (15 % BY VOLUME MIXTURE) EQUIPMENT USED – MIXER, PUMP, AND 528 FT. OF PIPE			
	AVERAGE VALUES		
	CONTROL	SINGLE PASS	150 PASSES
PERCENTAGE RETAINED OVER 1-1/8"	33.3	14.5	3.7
PERCENTAGE RETAINED 1-1/8" – 1/2"	56.6	61.0	57.3
PERCENTAGE PASSED 1/2" – 0	10.1	24.5	39.0

used for velocity determinations. The two rectangular chutes in the upper left carry the chips and water from the measuring tank back into the round mixing tank.

Fortunately, much is already known about the construction and use of pipelines for bulk transport. Therefore, the Institute concentrated on the three most important factors that would affect the use of pipelines specifically for transporting wood chips: (1) Are chips carried in a water mixture in a pipeline system, passing as they do through a mixer, one or more pumps and many miles of pipe, changed in any way that would be deleterious to their manufacture into pulp? (2) What concentration of chips can be carried through the system safely; does the mixture remain constant; and is there danger of plugging? (3) What friction losses are to be used in calculating power requirements for a pipeline system?

Chip Deterioration: To test the effect of the system on subsequent pulping, the chips were mixed with water and put through the pilot plant system under extremely severe conditions of mixing, pumping, and pipeline velocity. Continuous recirculation for 4 hours, or about 150 passes, developed conditions far more rigorous than those to be encountered in commercial practice. Samples removed from the discharge end of the pipe during and at the end of the test were compared with control chips from the original batch that had not been introduced into the system. Reduction in chip size is apparent from the abbreviated classification shown in chart on chip classification. After 150 passes, the proportion of chips less than 1/2 inch was 39 percent as compared to 10 percent in the control. Subsequent runs with identical chips and mixtures were made (1) with the mixer only, (2) with the mixer, pump, and a short piece of line, and (3) with the mixer, pump, and the full 528 feet of line. These runs showed that most of this reduction in chip size was caused by the pump; a smaller amount was caused by the mixer; and practically none was caused by passage through the pipe alone. Of course, far less reduction in chip size would be expected from improved equipment design and normal commercial practice than was experienced in these pilot plant experiments.

Next, samples of the chips obtained from the various tests and the control chips were cooked separately by the soda base sulphite process (considered most sensitive to chipper damage). The results are shown in the chart on cooking data. It is obvious that pulp quality was not appreciably decreased in any case. It is therefore safe to say that chip deterioration will not be a factor of consequence in pipeline transport.

Concentration of Chips in the Mixture: The next fact to determine was possible capacity of a pipeline. This involves the amount of solid wood that can be carried in mixture. To make the results directly applicable to all kinds and weights of wood, the concentration is expressed as a percentage of the volume of the mixture. Thus, if there are 15 cubic feet of solid wood of any specific gravity, any species or any moisture content in 100 cubic feet of the mixture of wood and water, the mixture is called 15 percent by volume. Mixtures higher than 50 percent are virtually impossible because the chips will not pack any tighter.

To test movement of various mixtures, a run was started with a mixture of 15 percent by volume, and chips were added steadily as the run continued. At about 35 percent by volume, the power consumption of the pump began to increase slightly, and it continued to increase until a 47 percent by volume mixture was being recirculated. By this time, the mixing operation became erratic, since the equipment was not designed for such heavy mixtures. The system was shut down and started up again a number of times at this mixture of 47 percent without any evidence of plugging or other difficulty. The results point to two conclusions: (1) As long as sufficient power is available, heavy concentrations caused by chips floating to the top of high sections in a line that is not in operation can be flushed out from the pump, and (2) the optimum commercial mixture is likely to be about 30 percent by volume. A further check on this second conclusion revealed that almost the same amount of pump power is required for water alone as for a 30 percent by volume mixture of chips and water.

Fig. 1.—Mixing tank and pump of pilot plant.

One should not get the impression at plugging is impossible. A chip ipeline can certainly be plugged if ie chips in it are allowed to become watered. If an attempt is then ade to flush them from the pump nd, the chips will form a plug about pipe diameters in length and this ill completely seal off the flow of ater. The plug can be removed nly by dismantling the line at the oint of blockage. The line may also blocked when the concentration chips is so high and so long that ie available pump power cannot ercome the increased friction used by this heavy mixture. With proper chip pipeline design and with proper controls and supervision, plugging should not occur.

Pump Power Consumption: Friction loss measurements have not yet been concluded. Preliminary power readings indicate, however, that power consumption for pumping mixtures up to 30 percent by volume is not substantially greater than that for pumping water alone.

Conclusions

The overall conclusions of the study, then, are:

(1) Chip deterioration is not a drawback to the operation of pulpwood chip pipelines.

(2) Mixtures containing 30 percent solid wood by volume can be handled.

(3) Friction losses and power requirements for mixtures are likely to be very close to those for water alone.

Pipeline Application

With this basic information available to add to the data known about pipelines, we might now consider an application in the woods. It would be easy to talk about a main pipeline of seventy-five miles leading from a final landing to the mill and to compare it with rail haul, truck haul, or river drive. Of course, getting 5 million cords to that same landing at the rate of 250,000 cords a year would be your problem. Instead, let us visualize a more complicated system of a main pipeline with feeder and branch pipelines that could be satisfied with 30,000 cords from each landing. The system can be quite flexible and it must be tailored to the individual forest rea. The beauty of the pipeline is hat it can go in any desired direction on the level, or up and down ill, and it can carry any species of oftwood or hardwood with equal ase.

Suppose that the forest tract is approximately 75 miles from the pulpmill it is to supply. The statistics are as follows:

Dimensions: 30 miles wide by 50 miles long.

Area: total 1,500 square miles—productive 900 square miles.

Total Volume: 5 million rough cords.

Stand per Acre: average 8 2/3 cords (for productive area) range 0–30 cords.

Total Period of Cut: 20 years.

Annual Cut: average 250,000 cords.

Location of Cut: It is proposed to establish 8 cutting areas per year, with each area producing 31,000 cords per year.

Cutting Areas: If the stand were evenly distributed over the tract, each of the 160 cutting areas producing 31,000 cords per year would be approximately 5 2/3 square miles in area. If the area were flat as well, its dimensions would be 2 3/8 miles wide by 2 3/8 miles long and the landing would be in the middle of it. This would practically never happen because the size and shape of each cutting area would be governed by the stand of timber, the topography of the cutting area itself and those adjacent to it. The same factors would govern the location of the landing.

Logging on the Cutting Area: Within each cutting area the trees are felled, limbed, topped, and moved as tree lengths, by some suitable skidding (or skidding and forwarding) system, to the landing that serves the whole cutting area. Alternatively, full trees could be skidded and the limbs and tops removed at the landing. Maximum skidding (or skidding plus forwarding) distance would be 1.7 miles from the far corners of the average stand in flat country. It would tend to be shorter in denser timber and could be longer in restricted topography, depending upon the dimensions of the cutting area and the location of the landing.

At the Landing: Tree lengths would be barked and chipped and then metered as chips into a stream of water feeding a small mixing tank. The mixture of chips and water would be drawn off the bottom of the mixing tank by a pump feeding a branch pipeline. These operations could presently be accomplished with equipment now on the market. Part of the time this should be carried on as a hot logging operation, but sufficient wood must be stockpiled at the landing to take care of variations in the arrival of logs because of shifts or days off, since barking, chipping, and pipeline operation should be carried on night and day all year. Eventually, a single processing plant might carry on these operations progressively and might handle full trees rather than tree lengths. By using bark as a fuel, a processing plant could generate its own power and have enough heat to thaw out frozen wood in very cold weather.

General Pipeline Specifications: In this example, aluminum pipe has been used throughout because of its light weight, non-corrosive properties and low friction loss. Figure 2 shows a layout of the proposed pipeline system needed to collect and transport 5 million cords during a 20-year period. It consists of surface-laid branch pipelines converging into a buried feeder line that empties into the buried main line. At the mill end, the chips will be removed from the mixture by a simple screening operation. Each of the eight branch lines would be extended about 2 3/8 miles to the landing of the next cutting area as soon as the operation is completed on the previous one. This would occur about once per year. When the maximum length of about 15 miles is reached, the whole branch line would be relocated.

Calculations of capacity and sizes shown in Figure No. 2 include a positive allowance of 5 feet per mile from the effect of gravity in the main line only, which is very small for most provinces in Canada. It is possible that main line pumps will not be needed in some locations where the average gradient exceeds 20 feet per mile. All friction losses were taken on the conservative side at 15 percent more than those for water alone.

Costs

In conclusion, here are a few cautious figures on what such a pipeline might cost initially and what it might cost to operate in terms of dollars per rough cord. It is estimated that costs are likely to be on the high side, but the operation still looks attractive.

The Aluminum Company of Canada has assisted in preparing pipeline costs per mile, based on its experience in areas similar to those encountered in woodlands. For 5-inch diameter surface-laid pipe for

branch lines, a figure of $10,000.00 per mile, installed and ready for operation, seems reasonable. A similar figure for buried 12-inch diameter feeder and main lines is $60,000.00 per mile. If 10 percent is added for power, pumping, water installation, and mill screening, the total investment is $7,000,000.00, or $1.40 per rough cord. The operating costs are as follows:

	Per Rough Cord
50 man crew to operate, maintain and move branch pipeline (at $3.50/hr.)	$1.70
Maintenance materials and miscellaneous costs	1.00
Depreciation	1.40
Interest on investment	.85
Total operating cost for transportation only	$4.95

If $16.00 per rough cord can be used to cover the cost of stumpage, taxes, felling, limbing, topping, skidding, handling, barking and chipping it appears that $21.00 per rough cord is a reasonable figure for the cost of chips ready for use at the mill. These figures could be lowered by more detailed engineering considerations.

This is merely a brief description of the project. It is a preliminary statement, and most of the substantiating data were omitted in the interests of brevity and simplicity. A final report on chip pipelines will show how the cost of pipeline transport can be calculated for a particular application. Furthermore, the pilot plant at the Institute will be available for a short time at least to make specific studies on a contract basis.

Perhaps the most important thing to remember about pipelines for woodlands use is that the chip pipeline is a high-capacity bulk carrier that must be kept running continuously, at or close to full capacity. In this respect it is more like the paper machine than a piece of logging equipment. Because of this it is necessary to develop a logging system around the pipeline, rather than to try to adapt the pipeline to an existing logging system.

Research ... Basic or Applied?[1]

H. W. BARLOW

Director, Washington State Institute of Technology Washington State University, Pullman, Wash.

- **How should a research program be planned to provide for optimum results?**
- **How much of it should be basic research, and how much applied?**
- **How much of it should be done in company laboratories; how much as a joint endeavor with other companies?**
- **How much of it can be profitably "farmed out," and to whom?**

THE QUESTIONS POSED IN THE HEADline of this article are some of the fundamental problems that need to be considered in the establishment of a research program for industry. They should be approached first by establishing what is meant by "basic research". A definition of basic research reported by the National Science Foundation (1) reads as follows: "Basic or Fundamental Research: Projects which are not identified with specific product or process application, but rather have the primary objective of adding to the over-all scientific knowledge of the firm". This is not a definition entirely accepted by academicians as defining their "pure" or "basic" research. but if it is good enough for the NFS, it should be good enough for us.

Basic research aims at producing new ideas. principles, and facts that will advance our total amount of fundamental knowledge. Basis research is an endeavor to find the true foundations which govern our universe.

I do not think that I need to define "applied research", as I am sure that all of you know what it is. To develop a new alloy of metal is *applied research;* to find the laws which govern behavior of metallic structures is *basic research.* To find better ways of joining wood by adhesives is *applied research;* to investigate the basic wood fiber to find out what gives it its chemical and physical properties and to find out how these can be changed is *basic research.*

Need for Research in Industry

How important is research in today's industrial picture? Is it only a way of increasing our tax deductions, or something in which the Department of Defense indulges to spend our tax money and literally shoot for the moon? On the contrary, it is an essential part of the bloodstream of industry. Without it industrial anemia can easily set in.

"The law of our present industrial society is the survival of the fittest (2). I do not refer to man or animal, or the development of superior genetic strains. Rather I refer to one's product, one's process, or one's material of construction. Each must perform in a superior manner or it is doomed to extinction; it must steadily be improved so that it can meet the competition of other materials.

"Neither old-fashioned salesmanship,, tradition, nor custom could have saved the horse and buggy from extinction; a superior product which has been steadily and consistently improved won out, and in turn, this changeover caused a dramatic change in our whole way of life.

"The only thing constant in today's world is 'change'. Man's imagination has left no part of our world or universe untouched. What has brought this about? The answer is research — that incessant quest for knowledge and improvement carried on by a minority group composed of scientists and engineers. They have dramatically changed our world as nothing has ever done before. Never in man's history

[1] Presented at the Wood Industries Conference, Portland, Oregon on September 10, 1959; recommended for publication January 13, 1960.

is one small group caused so much change in our world in so short a time."

Can the forest products industry point to any significant research that has had a comparable effect on that industry as, for example, the invention and development of the gasoline engine, the diesel engine, and the jet engine have had on transportation means?

What *is* the situation with regard to research in the lumber industry? How does it compare with other industries? There is not too much data available, but perhaps I can make some general comparisons. In 1952, according to a Harvard Business School study (3) involving 1,451 firms, the wood industry nationally, including pulp and paper, lumber and lumber products, wood preservation, and plywood and veneer shipped $14 billion worth of products and spent $26 million on research. This research expenditure was therefore 0.2 percent of product value. Lumber and lumber products exclusively spent $5 million on research for $6 billion of product or .08 percent for research.

In 1953 the industry expenditures for research was again 0.2 percent of sales.

A study made at WSC (4) in 1953 showed that in the State of Washington for 1953, the percent of research expenditures to sales in lumber and wood products, except furniture, was also 0.2 percent.

This figure of 0.2 percent can be compared with national averages in 1952 of 2 percent for industrial chemicals, 3.1 percent for drugs, 1.9 percent for paints, 0.9 percent for stone, clay and glass. In fact, in 1952 the lumber and wood products group was tied for low with the food industry (3).

Perhaps the 0.2 percent figure is a reasonable one, but it looks low as compared to expenditures by some of the makers of other products.

Another figure for 1953 is 0.24 percent of product value spent on research in forest products and utilization research by industries and public agencies, with 0.2 percent being the industry part. Small though it is, it is greater than the 0.02 percent in 1926 and 0.05 percent in 1937 (5).

Mr. B. B. Westcott, Vice President for Research of Gulf Oil Corporation, in response to the question of how much research a company could support, says in part, (6) "There are so many factors involved that there is no clear answer to this question. However, two important factors that immediately come to mind are:

"How much technology is a company capable of absorbing and utilizing effectively?

"How much money is available for the commercialization of research?

"The answer to the first of these questions calls for the exercise of knowledge and judgment gained from experience; to answer the second requires a thorough familiarity by research management with the current and future planning of the company management.

"The results of research are of value to a company only after they are put into commercial operation, and it adds nothing to the profits if a new process or a new product developed in research has to remain dormant as reports in the files, because of lack of capital funds for expansion."

Industry must be concerned with the "payoff" in research just as with any of its other operations. Superior judgment, adequate experience, and sound thinking are needed to back up the intestinal fortitude required to develop and sustain a research program that may show no immediate prospect of recovering its expenditures. An MIT study (7) showed that there is no true relationship between research and development expenditures and their results. One must buy research carefully. Big money can be lost faster and less conspicuously in research than in any other department of the business.

Basic Research in Support of Applied Research

The need for basic research has been given much "lip-service", but not enough real solid support. Applied research is much better understood and therefore gets more attention. Its results are more readily applicable. It takes a far-sighted executive to sponsor and support basic research, because sometimes that program may not seem to bear any direct relationship to the activities for whose success he is responsible. A board of directors may find some difficulty in justifying to the stockholders expenditures of thousands of dollars on basic research from which no tangible gains may be apparent for a number of years. Nevertheless, the need to advance our frontiers of knowledge in all directions is fundamental to our industrial progress. Unless we add to our storehouse of basic knowledge, the most we can do is to continue to elaborate on the phases of those things which we already know.

I would like to paraphrase an illustration by Dr. Eric Walker, President of Pennsylvania State University (8). What he has to say applies to basic research and the people who will be trained to do it.

". . . This new world promises rewards that stagger the imagination. It has already given us the ability to change, rather than merely to adapt, nature to suit our needs. It has already given us a source of energy that will probably solve for all foreseeable time our power needs. It has already given us cures or preventions for some of man's most persistent and most deadly ills. It has already given us the ability—if only on a small scale—to explore the space seas lying about our island world. It has already given us automation, which promises at long last to free man from manual labor. It has already changed, to a significant extent, the kind of work we do and the kind of lives we live. And it has already shown us that the discoveries made so far are like the visible part of an iceberg—that which lies hidden beneath the surface bulks larger than that which is now known.

"This is our real challenge—the extension and exploitation of this vast frontier. It is basically a challenge to man's capacity to know and to understand—to his capacity for mental intellectual development. The frontier itself is infinite, and our explorations into it are limited only by man's innate potential for disciplined and responsible intelligence and by the degree to which we are able to realize that potential.

"Perhaps an analogy will help. Each major scientific breakthrough is like opening a door into a room—a room whose use had been denied to man up to the opening of the door. Many other doors open from this room— doors we didn't even known existed before the opening of the first one. And behind each of these doors lie other rooms from which open other doors.

"These doors cannot be forced. They are impervious to the sheer weight of numbers or even to the slow erosion of time. Rather, they can be opened only by men of unusual talents—men equipped with enough insight and genius to discover the combination of the lock on the door, and with the proper tools for manipulating it.

"Our stake in the scientific age, then, depends on our ability to find these rare geniuses—these men who can open the doors to the unknown for us—and on our ability to cultivate their rare talents, to provide them with the proper tools, and to encourage them in their work. The demand is for both quality and quantity: Quality simply because the locks cannot be opened by ill-prepared, shoddily equipped workmen; quantity because, since each opened door discovers new ones to be opened, there will always be more

doors than there are people to open them."

The locks on these doors can be labeled "basic knowledge", and only with the combination called "basic research" in the hands of highly trained, imaginative people can we open the doors that will lead us to greater things.

We are too much inclined to assert that we have made wonderful progress in the last 50 years, that America's industrial revolution and splendid technological progress has put us at the "top of the heap", and that by merely continuing at this pace our future is assured. This philosophy needs closer scrutiny.

Mr. Walter J. Murphy, Editorial Director of Chemical & Engineering News, takes a hard look at our complacency in a recent issue (9) and points out (for example) that although the United States has built the largest chemical industry in the world, nevertheless in the field of pure chemical research, our country is tragically weak and relatively little is being done to correct the situation.

Many of the fundamental ideas in the chemical industry have come from Europe, and the list of basic chemical discoveries which have come from European laboratories is impressive as well as disturbing. Mr. Murphy wonders how we can continue to operate successfully in the future if we are to depend to such a great extent on pure research done abroad. "In years past, European industry has been too restricted to make effective use of these basic discoveries. Our ability to supply capital, plus large-scale manufacturing know-how, plus a large 'captive market' has enabled us to benefit from European inventions. However, the new European Common Market presents far stronger competition from abroad—a situation unlike anything we have faced before." You know the extent to which this applies to the wood products industry.

Ratio of Basic to Applied Research

The proper proportioning of the research program is a matter for intelligent executive decision. It is imperative that the same general principles that are used for the management of any other branch of the business should be applied to the management of research, including the establishment of the fundamental program.

There is no "pat" answer to the problem of proportioning the research dollar between basic and applied research. It is somewhat like the formula for a Martini—some people like them 2 to 1, others like them 3 to 1 and some like 4 to 1. Current support of all basic research by industry amounts to between $700 million and $800 million per year. This is about 7 percent of the current total research expenditures by American industry.

In 1953 (10) the chemicals and applied products industry spent 10.5 percent of its R & D funds for basic research; clay and glass spent 9.6 percent; American industry as a whole spent 4.1 percent of its R & D money for basic research. By 1957 this 4.1 percent had increased to 5 percent.

On this basis I would say that any company that is currently spending less than 5 percent of its research program on basic research is neither holding up its end of the load nor producing those basic ideas upon which successful application and the answer to competition will be based.

Basic Research in Industry

In order that there be a reasonable chance for pay-off of this suggested minimum of 5 percent in an industrial laboratory, certain other conditions must be established and maintained. The amount in dollars should not be less than that required to support continuously one full-time scientist or engineer in an adequately staffed, maintained, and equipped laboratory under conditions conducive to research output. Furthermore, it is vital that his most important asset, his thinking ability, be not continually harrassed and dissipated by interruptions and imposition of extraneous duties. Without belaboring what should be an obvious point, it seems appropriate in this discussion to stress the fact that dollars alone will not produce the desired results in an industrial atmosphere.

The average amount required to support this minimum program providing for one full-time research scientist or engineer in industry was $27,000 per year in 1953 for companies of over 1000 employees (10). This represented the salary of the principal researcher, plus that for 1.8 people as supporting personnel, plus operation costs and a reasonable amount for indirect costs. It would be higher now.

In addition, the average replacement costs of facilities per research scientist or engineer in 1953 was, coincidentally, $27,000. This would be higher for small companies. It is doubtful if many lumber companies in this country can support or justify this kind of expenditures in their own plant. One alternative is to support a basic research program in a university.

Even with adequate financial support, there may be other great difficulties in maintaining a program of basic research in the plant itself. Mr. Harold Gershinowitz, President of Shell Development Company (11), points up some of the difficulties involved: "In an industrial research laboratory one cannot have in the proper sense of the word anything called 'undirected research'. Some control must be maintained over the research program to make sure that the work on which the scientists are engaged does have some likelihood, at any given moment, of being used ultimately by someone eles in the organization; probably for the economic benefit of the company.

"In industrial research there is always a considerable amount of 'feedback'; that is, an interaction between the fundamental, long-range research and the application that is being made of it, because of the close physical and mental contact of the people doing different kinds of research. Ideas must come back from the application to the researcher in fundamentals. The fundamental man's program must be channeled into directions which do have a close relevance to the applied research. It is not so difficult to find men to do applied research—that is, good scientists who are willing to 'lower themselves' to apply their scientific training to some useful form of knowledge. Rather, the great problem is to keep people working on the fundamental and long-range problems. They become so intrigued by the ways in which their fundamental research can be applied that they tend to go off the fundamental and long-range and into the applied. Hence, we have a great deal of difficulty maintaining our fundamental research activities."

Basic Research in Universities

At a university the situation is somewhat different. Here, the research worker operates in an atmosphere in which the quest for basic knowledge is a normal way of life. He is surrounded by questioning colleagues in his own and related fields, by extensive library facilities, and by the precision tools of his profession. Left to their own devices, these people are likely to gravitate to programs which will run high in content of basic research. It follows, therefore that dollars spent for basic research at universities stand a better chance of yielding reliable, worthwhile knowledge to form the stepping stones or keystones to technical progress.

Unless one has visited some of the modern university research laboratories recently, he may have the erroneous impression that research in an educational institution is largely the activity of a few puttering, near-sighted professors who have nothing better to do. If you have that notion, I'd like to correct it and show that university research is big business.

In the fiscal year 1954, the federal government spent $280 million on research in universities (12). In 1957 was $377 million (13); in 1958 e estimate was $450 million; and in 59 it will be nearly $500 million. his is for federally sponsored research only.

Lacking any authentic survey data, is estimated that $1.4 billion will be nt in total by industry and governent in university research laboratories 1959 (14). Probably 25 to 35 per- t of this will be in basic research.

One of the questions that I was asked to discuss was "Can institutional laboratories perform a *better* service l spending more time on basic research?" This sounds like a "loaded" question, and you can no more give a "yes" or "no" answer than you can answer the question about whether you have stopped beating your wife.

By "institutional laboratories", I mean laboratories in colleges and universities.

We might open the discussion by considering the question of who should pay for basic research in institutions. Let us first consider the role of the federal government. Mr. Walter Murphy (15), whom I have quoted before, says, "There is danger in creating a socialist state in research. If government takes over directly, or even to a considerable degree, then there is danger that those who appropriate and those who administer the funds will decide not only the amounts, but how, where, and by whom they are spent and on what."

There are some areas in which assistance of the federal government is needed. We must recognize that support for the large and costly research tools in organized effects must depend almost uniquely upon federal support. The number of tools or facilities to be constructed for programs to be carried out on a national basis are necessarily small, often only one. However, the sums involved are necessarily large with respect to the budgets of state or industrial activities. Furthermore, benefits to be derived from such activities are general and extend to the whole of the country; their support is beyond the immediate interest of any smaller organization or unit. The federal government cannot escape responsibility for the construction and operation of such a very large research tool r the financing of integrated research rograms. To the extent that such tools limit scientific growth, the federal government has the power to make or reak great progress in research.

The National Science Foundation as created to develop the program basic research in this country through industries, private research organizations, and educational institutions. The National Science Foundation program will have nothing to do with applied research or any research that seems immediately useful (we found this out the hard way). This program of the federal government is a much-needed one and has resulted in a large increase in the basic research program in our educational institutions. The drawbacks are that it takes so long to get the money after a project has been submitted, and there are too few funds for the requests that come in. Nevertheless, results of this program will be enormous and will be felt throughout the nation for centuries to come. Through this program many young men with superior talent are being educated into the ways of research, and many basic research studies are being made.

My great fear is that sentiment for the state or federal government to finance all or the major part of our nation-wide program of basic research will lead industry to the belief that it can withdraw its support from such activities. I suppose this sentiment exists because industry cannot see the immediate payoff, (or sometimes any payoff) and therefore the research seems unproductive and hence uneconomical. This is obviously a short-sighted point of view, and all of us should seriously question the desirability of the "Great White Father" picking up most, if not all, the check on basic research.

There are those who believe that the program of the educational institution should be limited to basic research. I do not agree. I think that the institution's program should be a balanced one, just as should industry's program. A research program that is unnaturally limited soon becomes a barren one. In engineering, particularly, the faculty should engage in research as well as in professional practice. Faculty members should be in contact with modern activities and developments, and involved in basic and applied research. Otherwise they will soon be limited to explaining only what has been done in the last 20 years or be so far in the future as to lose contact with their students.

There are some who contend that the research program of the academic institution should be restricted to that which contributes directly to the academic program. This is also debatable. It implies that the universities which accept money for research that is not directly related to the support of their academic program are going commercial. Proponents of this argument are just not familiar with the practical facts of life. Let me explain what lies behind a seemingly unacademic statement.

The Land-Grant Colleges in this country long ago established a tradition of service to agriculture, to the public, and to industry. This tradition has been extended and accepted by nearly all of our colleges and universities. It goes much further than the matter of teaching the young people who enter our doors. You have only to read your daily papers to find examples of extracurricular and extramural services rendered by private as well as publicly-supported institutions.

In our particular case, we believe that we have an obligation to render service to industry, even in those activities which sometimes seem remote from any academic program. When industry cannot reasonably get the kind of assistance that it needs on its problems (and by "reasonably", I mean at a reasonable time, at a reasonable cost, and within a reasonable distance from its plant) and wants us to do the job, we think we ought to undertake it, consistent with our other obligations and availability of competent staff. The rendering of such service helps the industrial growth and hence the economic development and prosperity of the state.

It may be that in Buffalo, New York, or Columbus, Ohio, the research program of the institutions should be limited to that which contributes directly to the academic program. This does not hold good in the Pacific Northwest, because in many cases our people and our industries have no one close to turn to other than us for research assistance. In more highly industrailized areas adequate commercial research and testing organizations have been established.

Industry Support of Basic Research in Universities

What I have called to your attention are some of the prime factors in the modern philosophies relating to research in universities. An institution that is honored with support for a research program for industry should be looked into carefully to insure that the philosophies and policies of the company and the university are compatible. One should determine that the faculty or staff is adequate, highly motivated, and interested; that equipment and facilities are available; that the researcher will have time to work on the program; and that the team approach is possible and even probable.

If you would like a few criteria for the selection of suitable institutions, I would say they were these:

1. The faculty member or members have a competence in the field in

which the research is to be pursued.

2. The faculty have an intense interest in research in this area.
3. The faculty have been pursuing research in the general area on their own, and the industry's contribution is somewhat a grant-aid to a program which has already been started.
4. The faculty have time in which to pursue the research, and by this I mean more than 2 or 3 hours a week.
5. The administration of the institution is favorable to the program and will permit the staff member to take it on as a part of his regular load, not as an addition to it.
6. There will be a strong endeavor to interest graduate students in the work.

The assignment of both basic and applied research programs by industry to the colleges, and the generous financial support of those programs, will pay rich dividends to industry, both directly and indirectly.

The principal products of research programs are trained men as well as ideas, goods and processes. If we overlook the importance of training men, we neglect the source from which the future supply of ideas and goods will come. Trained men are therefore a factor of prime importance in any research program. This is why support of university research programs is of vital importance to industry.

Furthermore, the university framework can provide the means of the greatly needed expansion in basic research. Industries can hardly be interested in knowledge *per se* and not in profit. It is no accident that persons best suited to individual research are more often found in the faculties of colleges and universities. The diversity of the university atmosphere can react to broaden the interests of the individual and provide the intellectual tools required to associate diverse facts.

One wonders how much longer the forest products industry can go without appreciably expanding its basic research program. It is essential to know more about the basic physical and chemical properties of wood if new products are to be developed. These new products will enable the wood products industry to meet the competition of the new materials from other fields that are beginning to crash the party that you thought was yours exclusively. Basic research is a necessity; it is not simply a luxurious exercise to be indulged in by a few university professors. It is the solid foundation on which the progress in your industry will depend.

Currently, wood is used as supporting structure or in providing shelter for people or factories. I am sure you must have though often of why most of our houses must be made by nailing boards together. I mean hand-hammering nails into two boards to hold them together. The few known developments in the prefabrication of houses have barely scratched the surface of an enormous field of operation into which the lumber manufacturing industry must dive if it is to live. Is it possible that this long-sought and long-awaited development is blocked by a void (to mix metaphors) in the basic knowledge of wood properties?

In conclusion, if you believe that what I have said here today is a reasonable picture of the avenue to survival for us all, then it is time for you to take some action. If you believe that basic research is in great need of support and understanding, then I would urge that you make a thorough assessment of your own operations and determine the extent of your possible participation in the over-all massive effort to increase the world's fund of basic knowledge. It should not be too difficult, in the light of your present research effort, your product life-expectancy, your competitor's activities, your raw materials forecasts, your net profits, and your own conscience, to arrive at some dollar amount which represents your concern for the long-range future of your industry. This is the amount you should invest in basic research. Whether this is to be invested in your own laboratory or at an institution is another decision.

If the amount is too small to support basic research in your own laboratory with any reasonable hope of a reliable contribution to knowledge, then it should be evident to you that it can, with equal or greater return to you, be invested at your favorite institution. The choice of institution needs to be made with judgment, as I have pointed out previously. Once this decision is made, it is important that you keep in mind the fact that you should and will be able to do very little to control the expenditure, and that probably you will never be able to measure the return to you in dollars. The benefits you should seek are primarily intangible, such as increased faith in the future and the effect of this faith on day-to-day decisions; but benefits may also be quite direct if 10 or 20 years from now, for example, you can still claim to be actively in business. You may not at that time be able to trace the stepping stones of knowledge that led to this desirable situation, but no intelligent person will doubt that a major role is being played by the unheralded and unglamorous activities of research workers in the basic fields.

We are long past-due for a more concerted effort in basic research on wood. It is time for you in the wood-based industries to realize that you are of common flesh with other industries when it comes to dependence upon research for survival. Do not delay too long taking stock of the situation and doing something definite about it.

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Pneumatic Dunnage Reduces Damage Claims on Plywood Shipments[1]

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THE UNITED STATES PLYWOOD CORporation along with several other industries, has been using inflatable dunnage for the past few years, and has found that it facilitates loading and lowers costs of rail car blocking.

The idea of inflatable dunnage was originally conceived by the United States Army Quarter Master Corps and was developed by them and the United States Rubber Company. Inflatable dunnage is also known as air-bag blocking, rubber-bag blocking, pneumatic dunnage, or balloon dunnage. We are using the U.S. Rubber Company's "Shor-Kwik" bag and these bags carry a two-year guarantee.

The dunnage consists of an outer-casing, made of a nylon fabric coated with neoprene and an inner-bladder, much like a football made of a butyl-compound. The combination of these two materials make the bag weather-proof and abrasive resistant. In one end near the edge is a valve which is used to either inflate or deflate the bag. The bags are available in 4-foot widths and 5-to 9-foot lengths in 1-foot increments.

The bags replace most center blocking in the car and they eliminate the need for most other blocking. Conventional lumber blocking is still used in conjunction with the bags when mixed lengths or widths are loaded. Whenever it is necessary to use lumber for bulk heading behind short lengths, the bulk heading is placed near the end of the car so we always have a solid plywood face to place against the bags. The top units of each pile are strapped to insure that they remain intact during transit. In addition, the entire pile next to each side of the bag is strapped with a single 1¼-inch strap to prevent the panels from "climbing" the rubber bag during transit. The bags are placed in the center void of a loaded car. Normally two bags are placed side by side in a vertical position. The length of bag used is determined by the load height. If the load height is 4 feet or less, a single bag is placed horizontally on its edge.

[1] Presented at the Wood Industries Conference, Portland, Oregon, September 10, 1959; recommended for publication March 3, 1960

Bag dunnage is designed to fill a 3- to 10-inch space; therefore, cars have to be loaded with that limitation in mind. It is possible to use more than a single bag thickness, and some industries do, to fill a gap. With plywood loads, however, it has been quite simple to limit the center gap to less than 10 inches.

Inflatable—rubber-bag—dunnage saves United States Plywood Corp. mills $6.90 per rail shipment of plywood. Its use has practically eliminated damage claims. Customers are accepting the new type of shoring because it reduces unloading time.

Occasionally the inflatable dunnage is damaged. Damage to an unprotected bag can be quite extensive and expensive. U.S. Plywood found that the most damage occurred from the abrasive action of the plywood edges against the bag sides during transit. To prevent this damage, a 3/16- or 7/32-inch scrap veneer was placed between the bag and the plywood edges as a buffer. This has resulted in halting virtually all the in-transit abrasive damage.

When a car of plywood has been loaded the buffer boards are installed and a partially inflated bag of the proper size is inserted with the air valve towards the loading door. The bag is then inflated to the proper pressure—7 lbs. psi in summer months and 9 pounds in the winter months.

The continuous force exerted by the inflated bag against the loads does not allow sideways or lateral shifting; therefore, another costly part of normal car loading—side bracing—is eliminated. This results in a saving of $8.49 per car.

The elimination of side bracings relieved the possibility of their breaking in transit and causing damage which often led to time and effort spent by the company, and the delivering carrier, trying to decide who was at fault. This all has become a thing of the past with the advent of inflatable dunnage.

The use of inflatable dunnage for car blocking results in direct labor savings for both the loading and unloading; and the cost of the dunnage material is somewhat less with this method of car loading. Car loading time has been reduced 2.7 hours per car, and loading effort has been reduced 72 percent by the use of inflatable dunnage.

It is too early now to determine accurately if the life of the bags can be extended past the 2-year guarantee period, however, all evidence points to at least a 3-year life.

These bags cost from $70.00 to $120.00, depending on size. The average cost for U.S. Plywood plants is $86.00 per bag. This is based on the following tabulation.

VALUE OF BAGS USED

Size—feet	Cost	Est. % used percent
4 x 5	$ 69.50	30
4 x 6	79.50	30
4 x 7	99.50	30
4 x 8	109.50	5
4 x 9	120.50	5

If the bag cost is amortized over a 3-year period, and the cost of the 1¼ inch steel strap is added, there is a material savings of $1.50 per car. This $1.50 added to the labor savings of $5.40 gives a total saving of $6.90 per car.

In each car shipped, using air bag dunnage, a sack is included for the return of the inflatable dunnage. The unloading crew merely deflates the dunnage, folds it up and inserts it into the self-addressed sack and it is sent on its way.

The cost of returning the deflated bag is handled as an expense item and charged to the warehouse. The mill prepares the bill of lading for the bag's return and marks it "return collect", using the routing of the nearest branch warehouse and the customer's location. The mill accounting department pays the collect freight bill and in turn charges it to the branch. This is the least expensive and surest way

of receiving the bags back at the proper point. The cost of returning two bags is between $4.00 and $6.00, depending, of course, on the distance they must be returned. The average time "out" per bag is 5 weeks.

When the bags are returned to the mill, each is inflated with 5 pounds of air for a 2-hour test period. Any leak discovered is repaired much in the same manner as patching an automobile inner tube.

The greatest single saving is probably in the reduction of paid claims attributed to damage in transit. Also, the overall car loading and unloading time has been reduced approximately 10 percent by use of the rubber bags. Customer resistance has been a great problem, but it is rapidly disappearing. The customers were reluctant to assume the responsibility of promptly returning the bag. Now they are billed for the bags in the same manner as other companies bill their customers for returnable containers. Along with this, there has been an attempt to show customers that the savings to them offsets the effort required to return the bags.

The authors' company has placed a placard on each car which utilizes rubber bag dunnage, reading: "This car has been loaded using inflatable rubber dunnage to help you: 1) Reduce unloading time, 2) Reduce damage in transit, and 3) Reduce car clean up and dunnage disposal problems."

One corner of this placard contains a tear-out business reply card on which the customer is requested to fill out and return, describing the arrival condition. Of the returned cards, 98 percent indicate either excellent or good arrival condition.

WORLD-WIDE Forest Products News

Canadian Lab Aids Chemotherapy Progress

In a systematic study of the chemistry of western red cedar, chemists at the Vancouver Laboratory, Forest Products Laboratories of Canada, have isolated a variety of chemicals which have structures that might possibly be useful in chemotherapy. Accordingly, samples of the various chemicals have been prepared and submitted to organizations which are equipped to determine if the chemicals have any therapeutic activity. To date no activity justifying commercial exploitation has been found, although both the thujaplicins andthe polyphenols of cedar have been shown to have antibiotic properties. Currently, derivatives of plicatic acid, which is the main polyphenol of cedar, are being prepared for testing for activity in cancer chemotherapy. These derivatives merit testing because their chemical structure is similar to substances known to be active in tumour size reduction.

Course Given in Aerial Forest Inventory

The world's first international training course in aerial forest inventory has recently begun in Kuala Lumpur, Federation of Malaya, aimed at increasing the use of tropical forest area. It has been organized by the Food and Agricultural Organization of the United Nations in cooperation with the governments of the Federation of Malaya and British North Borneo, with the support of other organizations including the Colombo Plan.

In order to make full use of the existing forest potential, inventories of area, growing stock and growth are needed before increased felling can take place. FAO officials state that tropical forest areas provide one of the new remaining major strongholds of forest reserve, but until very recently, terrain and climatic conditions have limited inventory work in these areas. However, the advent of aerial photography and subsequent sampling procedures have made many of these obstacles obsolete, and applications of these methods to forest inventory has made a decisive contribution to the world's timber output.

Inventory methods (including the use of aerial photography) are far from being standardized. This course will provide an opportunity for discussion of the problems involved through exchange of experience.

International Society Promotes Wood Products

Scientists from the nine countries of Belgium, France, Germany, Great Britain, Italy, Norway, Netherelands, Sweden, and Switzerland, have launched a new international body to promote the advancement of knowledge and the more efficient utilization of wood and wood products. The initiating meeting of the International Wood Research Society took place in Paris at the Centre Technique du Bois on 27–28 May under the auspices of the Food and Agriculture Organization (FAO).

Dr. E. Glesinger, Director of FAO's Forestry and Forest Products Division, who represented FAO at the Paris meeting pointed out that "the new organization is a non-governmental association, composed of individuals as well as private enterprises or governmental agencies working in the fields of research, education and the technical aspects of wood processing and utilization".

Dr. B. Thunell, Sweden, was named President and Prof. J. Campredon, France, and Dr. L. J. Markwardt, U.S.A., Vice Presidents of the new Society.

The Society's purpose, Mr. Thunell stated in Paris, was to be fulfilled mainly through the exchange of information and ideas, by sponsoring meetings for the presentation of scientific papers, and by promoting cooperation among individuals, private and governmental agencies, and kindred national or regional organizations concerned with the utilization of wood and wood products.

Tokyo Meeting To Discuss Pulp and Paper Problems

The problem of developing the pulp and paper industry of Asia and the Far East is to be discussed later this year at a Conference jointly organized by ECAFE (United Nations Economic Commission for Asia and the Far East), BTAO (the Bureau of United Nations Technical Assistance Operations), and FAO. The meeting will take place in Tokyo, at the invitation of the Japanese Government, from 17 to 31 October. Invitations have been extended to member governments of ECAFE and member governments of FAO in the region, to Specialized Agencies of the United Nations, non-governmental organizations with consultative status, and to pulp and paper trade organizations.

Basic papers are being prepared by FAO in Rome and by ECAFE in Bangkok, and both organizations are co-operating in the conduct of case studies within the region. It is also expected that 60 to 80 papers will be submitted by independent experts in all the techniques involved. Under the U.N. Technical Assistance Program, the services of the Stanford Research Institute and two consultants have been engaged for case studies, and several discussion leaders have been engaged for the conference.

While attendance at the meeting will necessarily have to be limited, organizations wishing to receive further information or to apply for invitations should write to: FAO Forestry and Forest Products Division, Viale delle Terme di Caracalla, Rome, Italy; or to: ECAFE, Sala Santitham, Bangkok, Thailand.

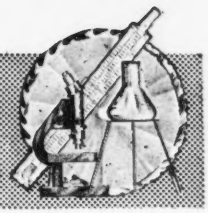
Russian Journal Translated

The Department of Scientific and Industrial Research has initiated a scheme for the translation and publication of Russian periodicals covering basic industries in order to inform industry in this country of research and development in the U.S.S.R.

The Timber Development Association has undertaken to produce the journal covering timber—"Industrial Wood Processing", for the D.S.I.R.

A complimentary copy of the first issue and subscription forms can be obtained on application from the Timber Development Association Ltd., 21, College Hill, London, E.C.4.

Abstracting the Literature



PROPERTIES

Hiett, Louis A., Beers, Walter L., Jr., and Zachariasen, Karsten A., (Buckeye Cellulose Corp.) Relationships between wood density and other wood and pulp properties. Tappi 43, no. 2:169–73 (Feb., 1960).

In connection with a tree-improvement program the effects of variations in wood d., within and among slash pine trees, have been studied. Within trees, variations in wood d. are accompanied by variations in springwood-summerwood ratio, pentosan content of wood and pulp, and α-cellulose content of pulp. Between trees, none of these props. appear to vary consistently with wood d., but between-tree variations in wood d. are indicated to be related to changes in the cross-sectional dimensions of both the springwood cells and the summerwood cells. Variations in paper strength props. with wood d. variations within a tree are greater than those caused by wood d. variations between trees. It is concluded that sp. gr. should be considered a factor in tree selection only to the extent that it influences wood (and pulp) yield. Addnl. studies may lead to a combining of sp. gr., springwood percentage, pentosan content, and α-cellulose (and possibly other factors such as fiber strength) into a pulp-quality index which can be evald. in judging tree superiority. 4 ref. (A.B.I.P.C. 30:10)

Marian, Joe E., and Wissing, Arne. The chemical and mechanical deterioration of wood in contact with iron. 1. Mechanical deterioration. Svensk Papperstidn. 63, no. 3; 47–57 (Feb. 15, 1960). [Engl.; Swed. and Ger. sum.] Lab. expts. under conditions simulating outdoor service exposure showed that wood in contact with actively rusting iron for prolonged periods of time suffers a considerable decrease of tensile strength, whereas compression strength is virtually unaffected under the same conditions. Parallel expts. on delignified holocellulose samples contg. only small amts. of lignin proved that delignification does not affect the tensile strength but reduces the compression strength. These observations indicated that contact of wood with corroding iron affects largely the holocellulose fraction, but not (or only slightly) the lignin portion. 27 ref. (A.B.I.P.C. 30:10)

Marian, Joe E., and Wissing, Arne. The chemical and mechanical deterioration of wood in contact with iron. 2. Chemical decomposition. Svensk Papperstidn. 63, no. 4 98–106 (Feb. 29, 1960). [Engl.; Swed. and Ger. sum.]

Chem. anal. of railroad crossties and other wood samples in prolonged contact with rusting iron confirmed earlier conclusions to the effect that such a contact affects mainly the holocellulose fraction of the wood. At least in the early stages of rusting, the chem. changes involve the decpn. of hemicellulose into alkali-sol. fission prods. This decpn. of wood polysaccharides is viewed as a metal catalyzed autoxidative chain reaction. This interpretation can explain the antioxidant efficiency of phenols, amines, and other easily oxidized substances, viz., by rapid combination with and destruction of free peroxide radicals. 15 ref. (A.B.I.P.C. 30:10)

Marian, Joe E., and Wissing, Arne. The chemical and mechanical deterioration of wood in contact with iron. 3. Effect of some wood preservatives. Svensk Papperstidn. 63, no. 5: 130–2 (March 15, 1960). [Engl. Swed. and Ger. sum.]

The chem. changes (holocellulose degradiation) which decrease the tensile (but not the compression) strength of wood in contact with corroding iron were found to take place even in preservative-treated wood. Although the impregnation of Scots pine *(pinus silvestris)* with creosote somewhat inhibited its deterioration (esp. of the sapwood) in contact with rusty iron, the presence of creosote caused a slight decrease in tensile strength when the wood was exposed to alternate flooding and air drying. Zinc-chromium arsenate (in higher than normal retentions) promoted th decpn. of wood by rusting iron. 5 ref. (A.B.I.P.C. 30:10)

Kleinert, T. N., Marraccini, L. M., and Dostal, E. J. (Pulp and Paper Research Inst. Can.) Alkali sorption on wood from dilute aqueous solutions. Tappi 43, no. 3: 201–8 (March, 1960).

The sorption of alkali from dil. aq. solns. of sodium hydroxide, alk. sodium zincate, sodium sulfide, and from com. kraft cooking liquor on small wood particles(spruce sawdust and poplar wafers) was studied, using particularly low alkalinities up to the concn. of com. white liquors. Max. sodium hydroxide sorption from sodium hydroxide-contg. liquors was obtained within a few min. without preceding deaeration, particularly if turbulent mixing of the resulting slurry was maintained during the reaction. At low sodium hydroxide concn., chemisorption was found to prevail. Further, a sorption plateau corresponding to a final liquor concn. between about 2 and 5% sodium hydroxide was found. By using a modified centrifuging technique, the alkali and water retentions of the trd. wood samples were detd., and a nearly const. ratio was found. The alkali and water retention values of the centrifuged samples were found to be insignificantly influenced by the initial moisture content of the wood. For instance, approx. the same retention values were obtained in samples ranging from a.d. wood to wood contg. 75% water. The sorption phenomena which occur when small wood subdivisions are reacted with alk. sodium zincate solns. of varying alkali and zinc oxide content were also studied. The presence of zinc oxide in the alk. liquors appreciably increased the alkali sorption, but the water retention increased only slightly. Finally, the alkali sorption from aq. sodium sulfide solns. and from com. kraft cooking liquor was investigated. Sodium hydroxide formed by hydrolysis of sodium sulfide in aq. solns. was preferentially sorbed and definite amts. of sulfur were taken up. There is evidence that the hydrosulfide ions are responsible for this sulfur sorption. From com. kraft cooking liquor contg. 27.2% effective alkali and having 25.4% sulfidity, the sulfur being present mainly as the sulfide ion, no sulfur sorption on wood was noticed. 23 ref. (A.B.I.P.C. 30:11)

Marian, Joe E., and Wissing, Arne. The chemical and mechanical deterioration of wood in contact with iron. 4. Prevention of deterioration. Svensk Papperstidn. 63, no. 6: 174–83 (March 31, 1960). [Engl.; Swed. and Ger. sum.] *cf.* A.B.I.P.C. 30: 1335–6.

Under the lab. conditions employed, the desired protection was achieved by galvanizing the iron or by applg. a water-resistant synt.-resin coating. Results with antioxidants and with generated or imposed elec. currents were difficult to interpret and indicated a need for further investigations into the importance of the elec. field. 6 ref. (A.B.I.P.C. 30:11)

Ladell, J. L. A method of measuring the amount and distribution of cell wall material in transverse microscope sections of wood. J. Inst. Wood Sci. no. 3: 43–56 (Sept., 1959).

The method consists of taking point samples at random on a transverse section and recording whether they fall on cell wall or on lumen. The proportion of points falling on cell wall give the percentage of cell wall matl. in the area sampled. In practice the samples are taken by projecting the image of the transverse section onto a card (the sampling field), which is pierced by 100 minute holes distributed at random. These, when illuminated from below, give 100 clearly visible sampling points on the projected image. The method is fast, easy to use, and probably more accurate than direct measurement. The diams. and cross-sectional areas of cells can easily be obtained at the same time. 1 ref. (A.B.I.P.C. 30:11)

LOGGING

McIntosh, J. A. How log loading affects utilization. Canada Lumberman, Jan., 1960: 4p. [Reprint]

The effects of log vol., log length, yarding methods, and available loading crew on forest utilization and productivity of logging operations were studied. Although variables made direct compari-

son of methods difficult, the flg. gen. conclusions were drawn: All sizes of logs, but esp. small-vol. logs, were loaded more economically by the air-tong and log-grapple method than by std. tongs. On a unit-vol. basis, long length was not a significant factor, except in one operation. The size of the loading crew was a definite economic and safety factor in favor of air tongs and log grapples; the skill of the operator contributed significantly to the efficiency of these handling units. (A.B.I.P.C. 30:11)

CHIP PREPARATION

Hansel, Sidney. Considerations on the construction and power demand of chipper installations with horizontal feed. Das Papier 14, no. 2: 56–8 (Feb., 1960). [Ger.; Engl. and Fr. sum.]

Deviating from the usual chipper design, in which the charge is supplied on sloping channels, a new horiz.-feed chipper has been constructed, in which the knives are positioned so that their edges do not aim at the center of the knife disk but are displaced somewhat parallel to the direction of rotation of the machine. Advantages of this new design principle have been demonstrated in pract. trials and include uniform passage of the wood and vibration-free operation requiring less massive foundations. Expenditures are reduced by installation of thin knives mounted in special pockets which facilitate their exchange and external adjustment according to the amt. of wear. (A.B.I.P.C. 30:10)

BOTANY

Zahur, Mohammad S. Comparative study of secondary phloem of 423 species of woody dicotyledons belonging to 85 families. Ithaca, N.Y., Cornell Univ. Agr. Expt. Sta., N.Y. State Col. of Agr., Memoir 358, 1959. 160 p.

The secondary phloem of 423 species of woody dicotyledons belonging to 85 families, mostly from the Hawaiian Islands, was studied to discover any existing trends of phylogenetic specialization. The study showed that secondary septation of the sieve-tube mother cells before maturation is a common feature in the angiosperm phloem. Its absence in gymnosperms and other lower vascular plants and its significant correlation with Gamopetalae suggest its advanced nature. The two flg. working hypotheses were derived from the data: The delay in specialization of the sieve-tube mother cells, or the retention of meristematic activity by these cells over a long period, has been an important factor in the phloem of woody dicots. The sieve-tube elts. have been shortened during the course of evolution in two different ways, viz., by a decrease in length of individual fusiform cambial initials, and by the appearance of secondary septa in the sieve-tube mother cells. Accompanying this over-all shortening of the sieve-tube elts. were a redn. in length of the end walls or sieve plates, a decrease in the no. of sieve areas in the end walls, and an increase in the size of the pores. Previous observations on the presence of slime and its connection with sieve plates were confirmed. In addn., the observed occurrence of nucleoli in the functionally active sieve-tube elts. of 41 angiosperms of various closely related families suggested their possible phylogenetic importance. Three different types of companion cells were distinguished, two of which seemed to be derived from the third type. No correlation was found between sieve-tube type and fiber type. Phloem parenchyma is highly variable and cannot be studied as readily as the xylem parenchyma in wood. 91 ref. (A.B.I.P.C. 30:11)

DENSITY VARIATION

Jeffers, J. N. R. Regression models of variation in specific gravity in four provenances of Sitka spruce. J. Inst. Wood Sci. no. 4: 44–9 (Dec., 1959).

This paper describes the statist. methods used to investigate the variation of nominal sp. gr. in samples taken from four provenances of Sitka spruce. Three regression equations gave reasonable approximations to the variation of sp. gr. The first two included, as indep. variables, the girth of the tree, and the linear and quadratic terms of the distance from the butt of the tree and the age of the ring, and differed only in the complexity of their interaction terms. The third equation included as addnl. variables the width of the annual ring and the moisture content of the timber at the time of testing. 1 ref. (A.B.I.P.C. 30:11)

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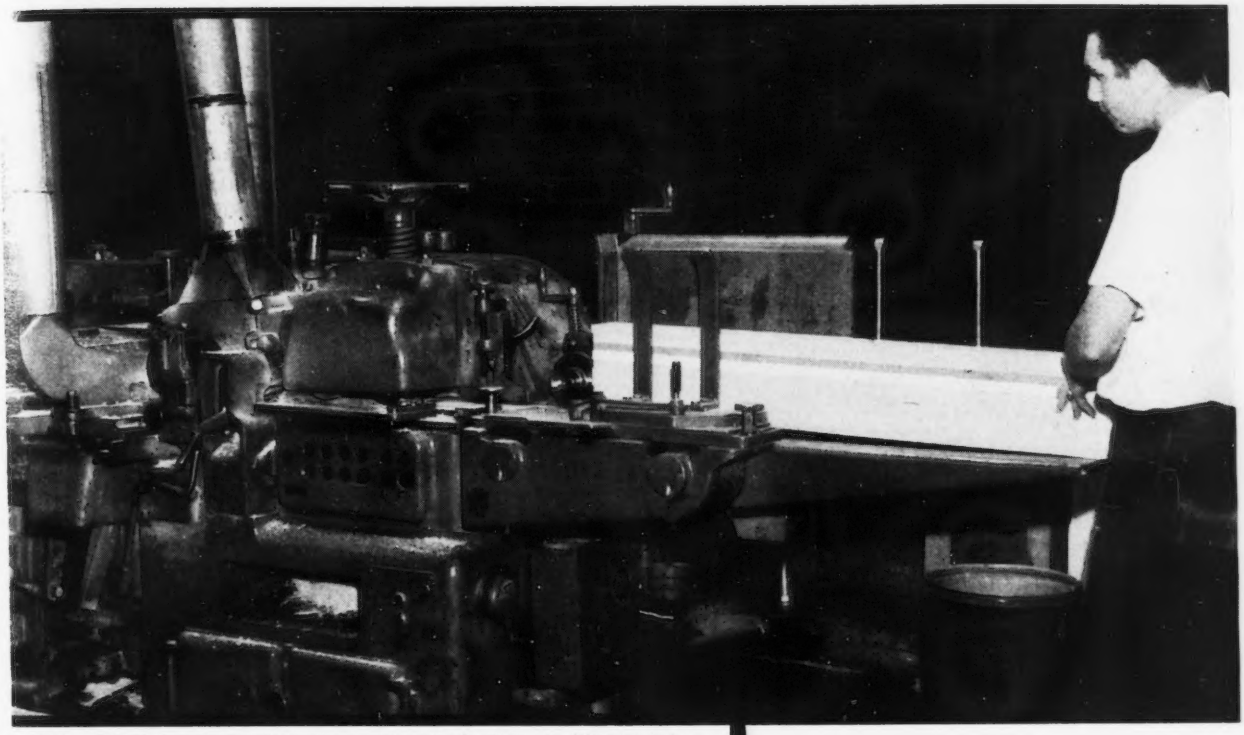

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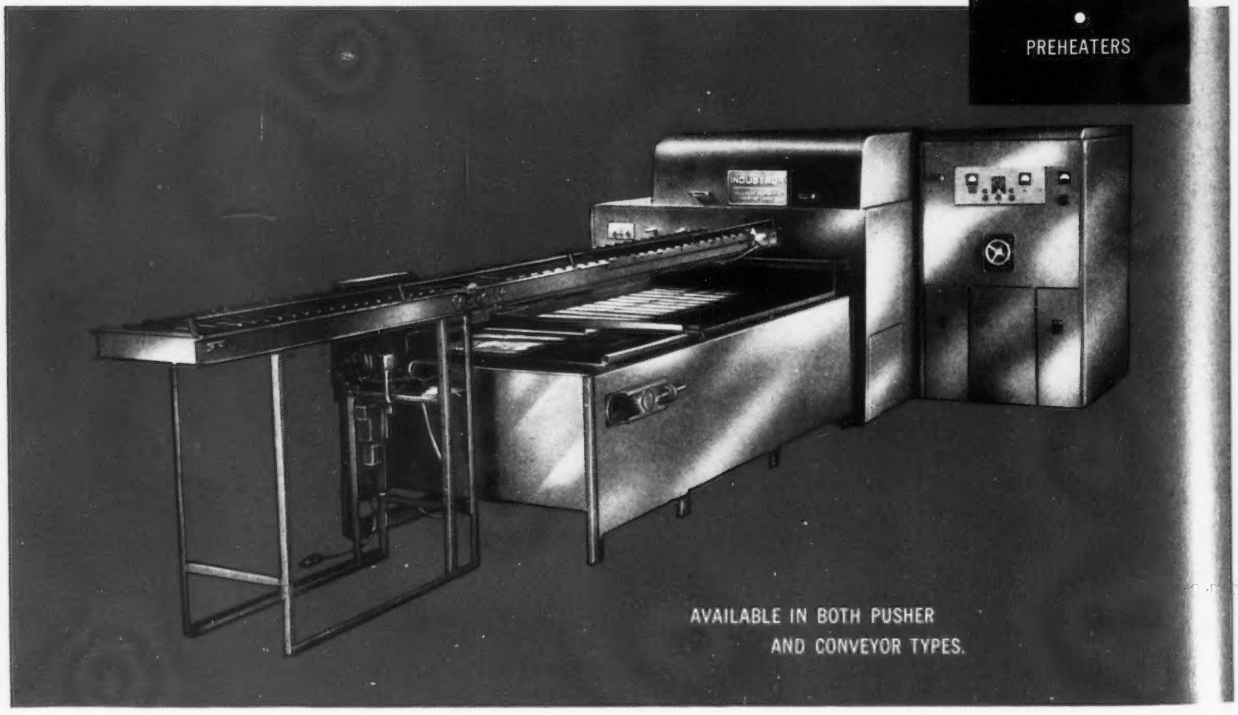

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